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Briefs of SAE PAPERS

These digests are provided by ENGINEERING INDEX, which each year abstracts 30,000 engineering articles from 1500 different publications and classifies them into 249 "fields of engineering interests."

To order the SAE papers digested here, circle the numbers in the "Readers Information Service" blank on p. 6 corresponding to the numbers appearing after the titles of the digests of the papers you want.

AEROSPACECRAFT

Notes on Results of Recent Tests of Momentum Exchange Type Silencer for Turbojet Engines, E. STRINGAS. Paper No. 162A. Review of momentum exchange theory for jet noise suppression; two exhaust nozzles were designed and tested utilizing flow concentricity technique, i.e., evaluating effect of area splitting on total sound power emitted by jet exhaust; experimental results and correlation of results obtained from tests; data exhibit peak to peak attenuation of 20 db along maximum exhaust noise azimuths at nozzle pressure ratio of 3.1.

By-Pass Engine Noise, F. B. GREATREX. Paper No. 162C. Examination of jet mixing processes; comparison of noise measurements made by Rolls-Royce on jet engine in flight and on ground; mixing process in ejector, circular and silencing nozzles; examination of approach noise and its calculation in terms of compressor characteristics; possible methods of reduction; it is found that jet noise of by-pass engine, of by-pass ratio around 1, designed for efficient mixing of by-pass and hot gas streams before being discharged to atmosphere, will be 4 db quieter than two streams discharged separately.

Resonant Fatigue Failures Associated with Noise, R. N. BINGMAN. Paper No. 164B. Characteristics of important noise sources and noise environments which induce damage; fatigue failures obtained in ground sonic fatigue tests conducted on four USAF multi-engine jet powered aircraft illustrate nature and extent of incidence of sonic fatigue; types of structural failure; need for establishment of design criteria enabling better prediction of sonic fatigue; structural design practices to reduce sonic fatigue; design development philosophy and inspection requirements.

Interplanetary Exploratory Vehicle, W. E. BEALL. Paper No. 165A. Relationship of aircraft industry and some present programs to future space activities; objectives of various space-research missions; organization of missions and objectives in Boeing "Program for Astronomical Research and Scientific Experiments Concerning Space" (PARSECS); conceptual vehicles for each mission are presented; problems of space-vehicle design and considerations leading to particular design concept; general-purpose space capsule is presented. 24 refs.

Nuclear Space Vehicles Using Pebble Bed Reactors, M. M. LEVOY, J. J. NEWGARD. Paper No. 165B. Problems and limitations of nuclear rockets which might be launched within next 10 yr; on basis of payload weight or overall cost, 60,000 lb vehicle is competitive with chemical vehicle; in range of flows for vehicle with I_s of 850 sec at about 10 to 20 lb/sec, pebble bed reactor with uranium loaded graphite pellets can be used without suffering excessive propellant pressure drop through core.

Electric Propulsion and Power Requirements for Space Vehicles, F. D. STULL, V. W. SHIEL. Paper No. 165C. Fundamentals of electric propulsion; description and characteristics of three types of thrust devices — electrostatic accelerators, electromagnetic accelerators, and thermal arc jets; possible missions listed which could be applicable for electric propulsion; power requirements presented in parametric form for specific missions of low-altitude sustainer and orbit transfers; off-optimum operations are considered in case of 200 to 22,300 mi orbit transfer.

New Design Approach for Supersonic Transports, C. L. BLAKE. Paper No. 166A. Contrary to opinions of manufacturers, airline operators claim that supersonic transport will be more complicated and more costly machine to operate; new design approach suggested in which computing machine program is developed which simulates

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complete airplane as far as reliability is concerned; characteristics of all components, subsystems and systems are included as well as their interactions and interdependencies; use of automatic "advisor."

Shock Wave Noise of Supersonic Aircraft, I. L. RYHMING, Y. A. YOLER, Y. AOKI. Paper No. 166B. Theoretical methods developed by G. B. WHITMAN and F. WALKDEN are used to study possibilities of using aerodynamic interference to reduce or suppress shock wave noise due to lift of conventional aircraft; wind tunnel experiments with wing body configurations are conducted and are analyzed in light of theoretical indications; further results of theoretical studies and wind tunnel experiments.

Supersonic Air Transports — Airline Talks Back, B. S. SHENSTONE. Paper No. 166C. Critical appraisal of use of Mach 3 aircraft by commercial airlines; aerodynamic, structural and power plant problems; economics of development and manufacturing costs indicate that Mach 2 aircraft may be feasible; lack of concrete cost data is hampering airlines in decision making.

Nuclear Rockets for Lifting Manned Stations into Space, H. F. CROUCH. Paper No. 167A. Generalized concept for manned nuclear rocket vehicle; potentialities of such vehicle, particularly its high lift capacity, maneuvering in orbit (i.e., rendezvous) controlled re-entry, and multi-manned capability; these capabilities are believed to be beyond those of chemical rockets.

Choice of Engine Type for Nuclear Powered Multi-Purpose Aircraft, D. P. LALOR, W. C. SCHMILL. Paper No. 167B. Report on studies conducted by Douglas Aircraft Co. to select best engine type for nuclear powered aircraft and determine feasibility of using one aircraft design for several missions; for nuclear system to be applied to multipurpose aircraft, (1) speed for maximum productivity does not change with engine type, (2) aircraft powered by turboprop engine systems are most productive, and (3) increases in cruise altitude decrease productivity.

Some Practical Methods for Fabricating Shields for Nuclear-Powered Aircraft, W. Q. HULLINGS, J. L. McDANIEL. Paper No. 167C. Studies conducted at Convair have indicated that from standpoint of cost, physical properties, fabrication ease, radiation damage, stability, and shielding capabilities, linear polyethylene with boron additive is potential material for use as neutron shield; physical properties and manufacturing aspects of borated linear polyethylene.

Ceramic Bodies and Coatings for Rocket Engine Applications, W. T. MONAGLE. Paper No. 168B. Tests conducted by Reaction Motors on materials used in engine system to operate at 50,000 lb thrust for 25 sec as booster unit for ground to air missile system; Crystolon N used as nozzle material showed almost no erosion or cracking; Niafrax A also tested satisfactorily; Speer Carbon Co Grade 3383 electrode graphite showed good results as combustion chamber and exit cone liner material; Rokide Z coating proved highly reliable in Guardian engines.

Structural and Insulative Characteristics of Ablating Plastics, F. A. VASSALLO, N. E. WAHL, G. A. STERBUTZEL, J. L. BEAL. Paper No. 168C. Report on tests conducted at Cornell Aeronautical Laboratory on glass- and asbestos-reinforced laminates under ablating conditions; temperature profiles within plastics determined as function of time and correlated with analytic expressions; strength of residual plastic was measured during ablation and expressed by empirical relation; heats of ablation and ablation temperatures of certain plastics were measured; degradation of materials was examined after ablation.

Nuclear Powered Airship, L. JURICH. Paper No. 169A. Airship is shown to be compatible with nuclear propulsion due mainly to low powers required for propulsion and separation distance available between crew personnel and reactor; typical nuclear airship config-

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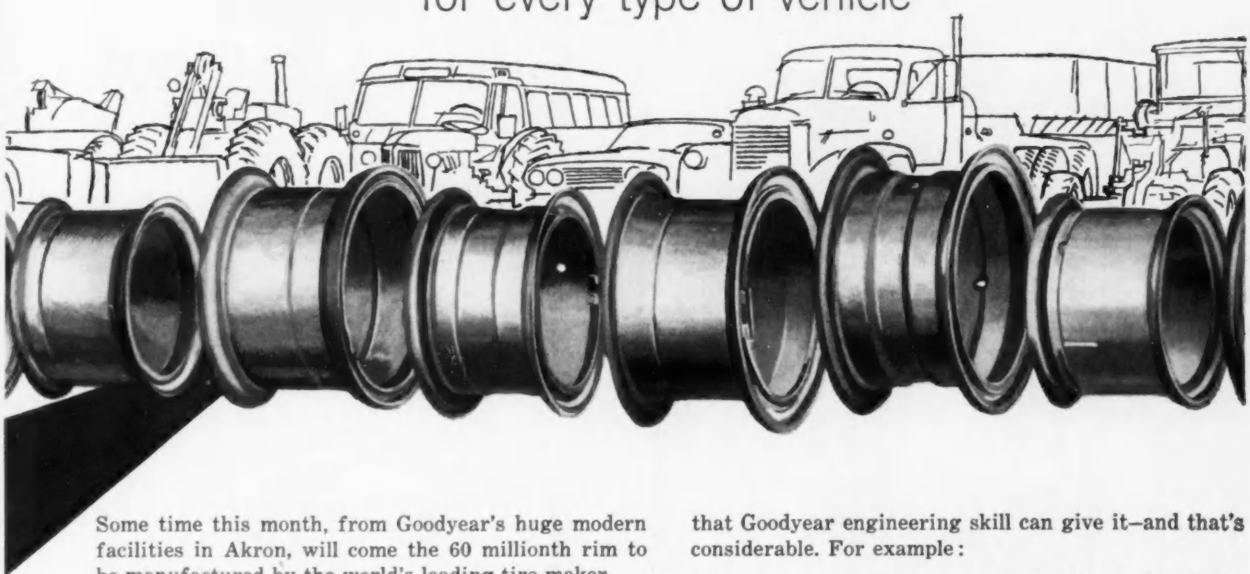
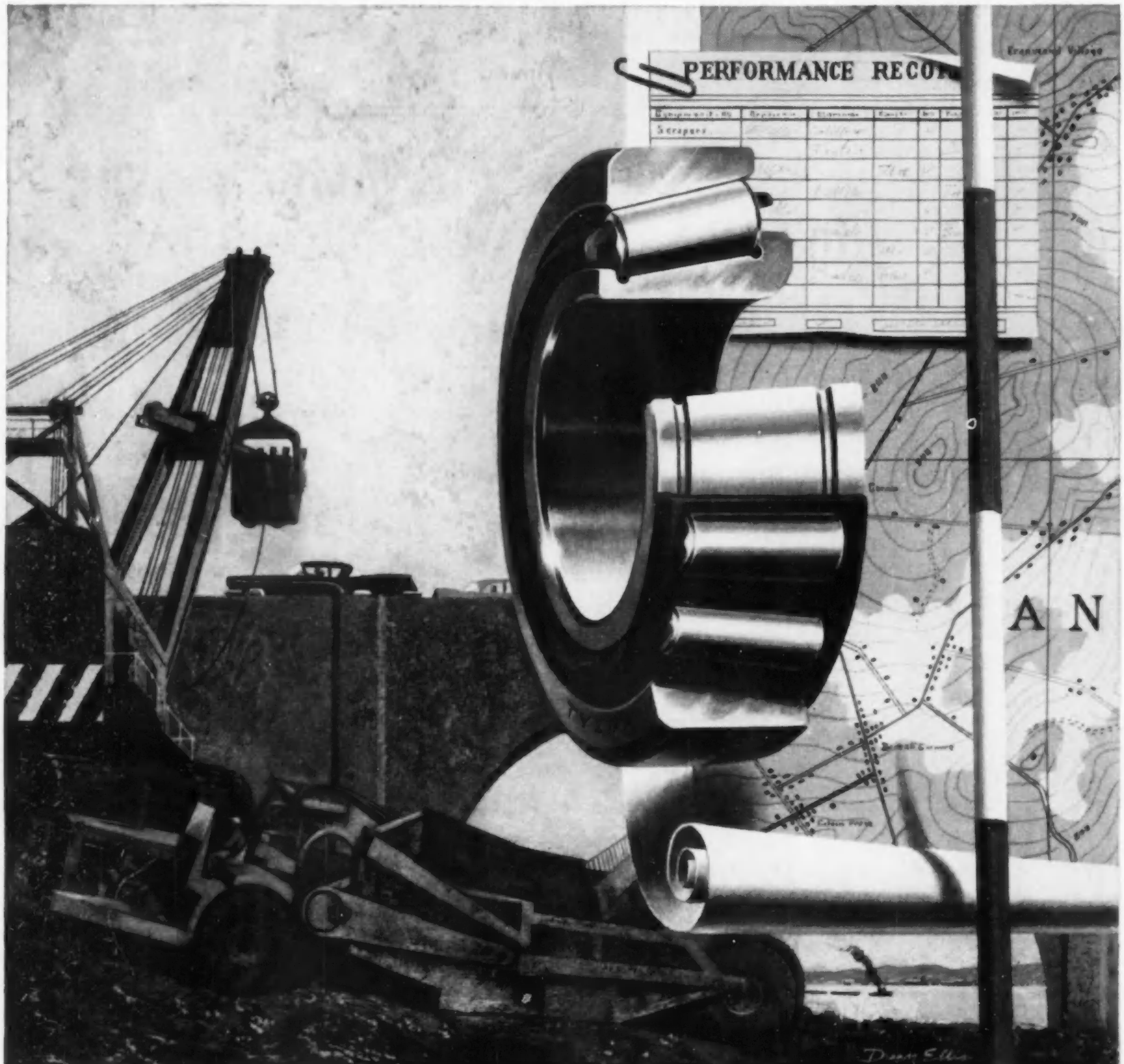



PERFORMANCE RECO
A N

New Springday V-Belt plant at Springfield, Mo., manufacturing arm of Dayton Industrial Products Co., was designed and built for the single purpose of producing better V-Belts, in quantity.

Here's why Dayton alone can build production V-Belts, in any quantity, with individual custom-built quality

New Springday plant sets higher standards of quality for Dayton V-Belts

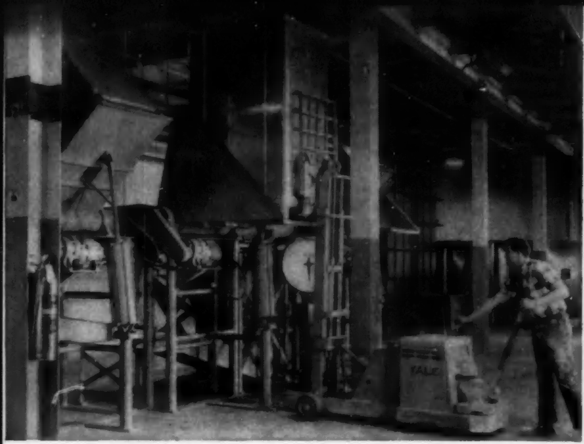
Here's real news for you, whether you buy V-Belts for O.E.M. or replacement applications. Dayton's new, completely automated Springday plant eliminates the need for spot-checking production belts, saves you time and money. This is possible because each Dayton V-Belt comes off the line in custom-designed quality at this new plant—the only one of its kind—built specifically and solely for the design and manufacture of V-Belts.

Designed from the "inside-out" by our own Central Engineering staff, this plant incorporates every known, reliable facility for effecting optimum product quality control, efficiency of production and delivery. Where existing machines would not meet the increased standards, new ones were designed, patented and built to do the job.

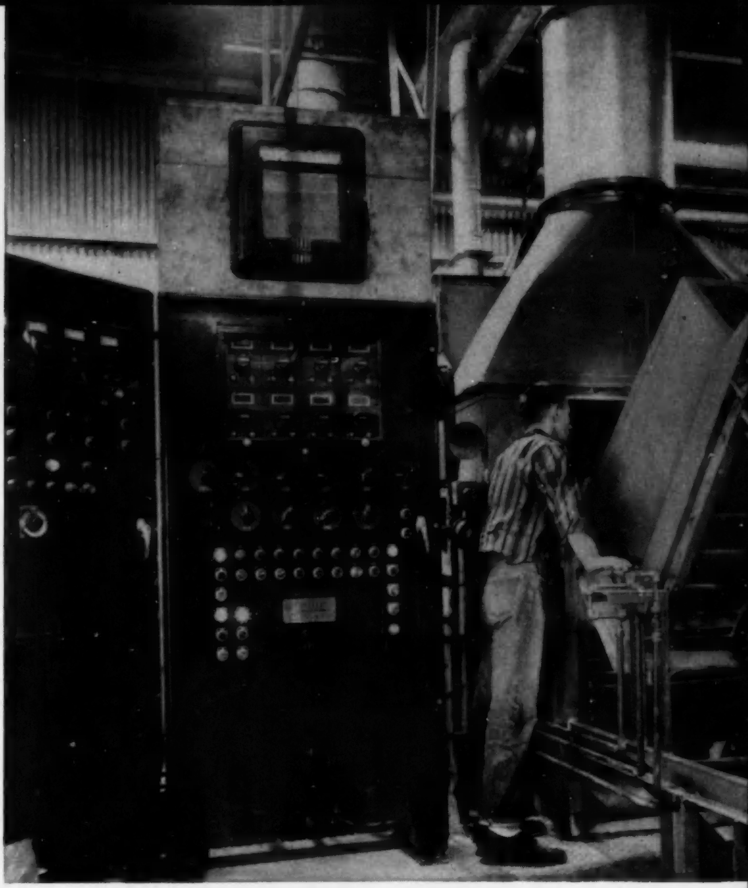
Recently awarded the distinction of being named by Factory Magazine as one of the Top Ten plants built in 1960, it has been referred to as "a masterpiece of plant layout and material handling . . . quickly became world's largest producer of V-Belts . . . a truly significant plant."

We, too, feel it is a significant plant; principally, however, because it can and is mass producing Dayton Automotive O.E.M. V-Belts to an individual excellence of quality that would not be possible to achieve by a multi-product plant. Here are a few of the reasons why—

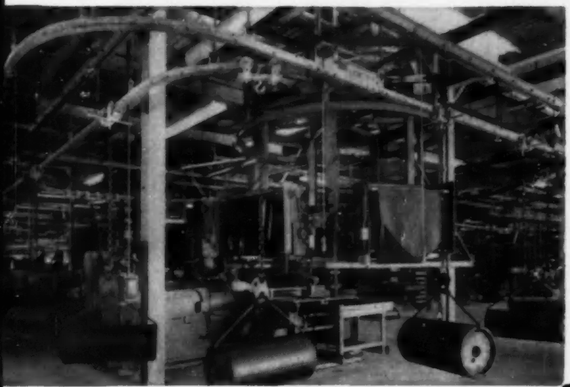
Foolproof mixing. Dayton's new monorail unit moves along overhead track as operator weighs out dry ingredients and oils, used to condition rubber stocks, according to exact formula required.



▲ **Dustless Handling of Carbon Black** is masterpiece of materials handling. Containers are placed in position by fork lift truck; automatically open to add carbon black via auger-type feed, correct amount is measured electronically.

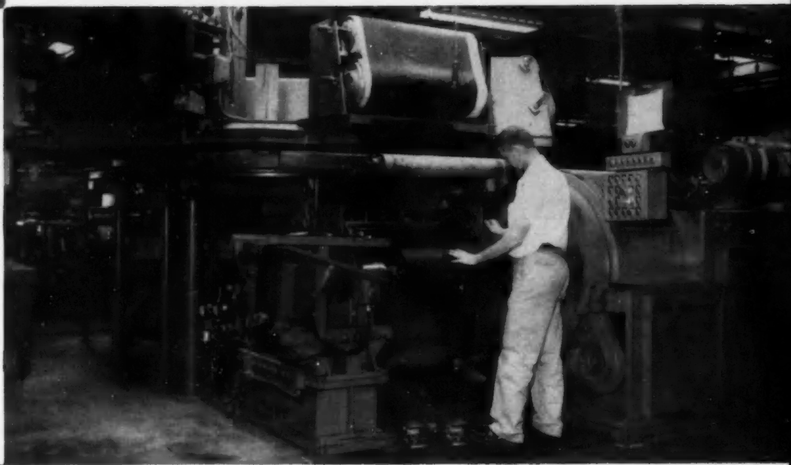


▲ **Automatic loading of new stock** into Banbury Mixer speeds mixing, assures continous flow of stock to collanders. Collanders roll stock to precision thickness for belt making.

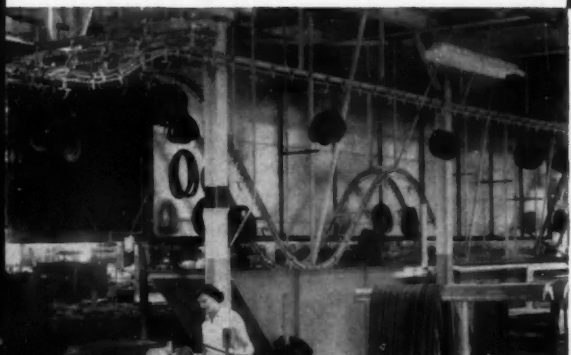


▲ **New Multi-station Belt making machine** applies rubber stock in correct ply layers. Belt-making drums are delivered to and removed from machine by continuous overhead conveyor.

Many patented and exclusive innovations and improvements in belt building assure optimum production and quality control. This rotating Carousel provides operator with 6 different types of ply stock at the touch of a pedal. ▶



Final check "sag" test. Each belt receives Dayton's special "sag" test to insure proper belt matching. In background, uncured belts are carried by conveyors to curing room. ▼



Dayco

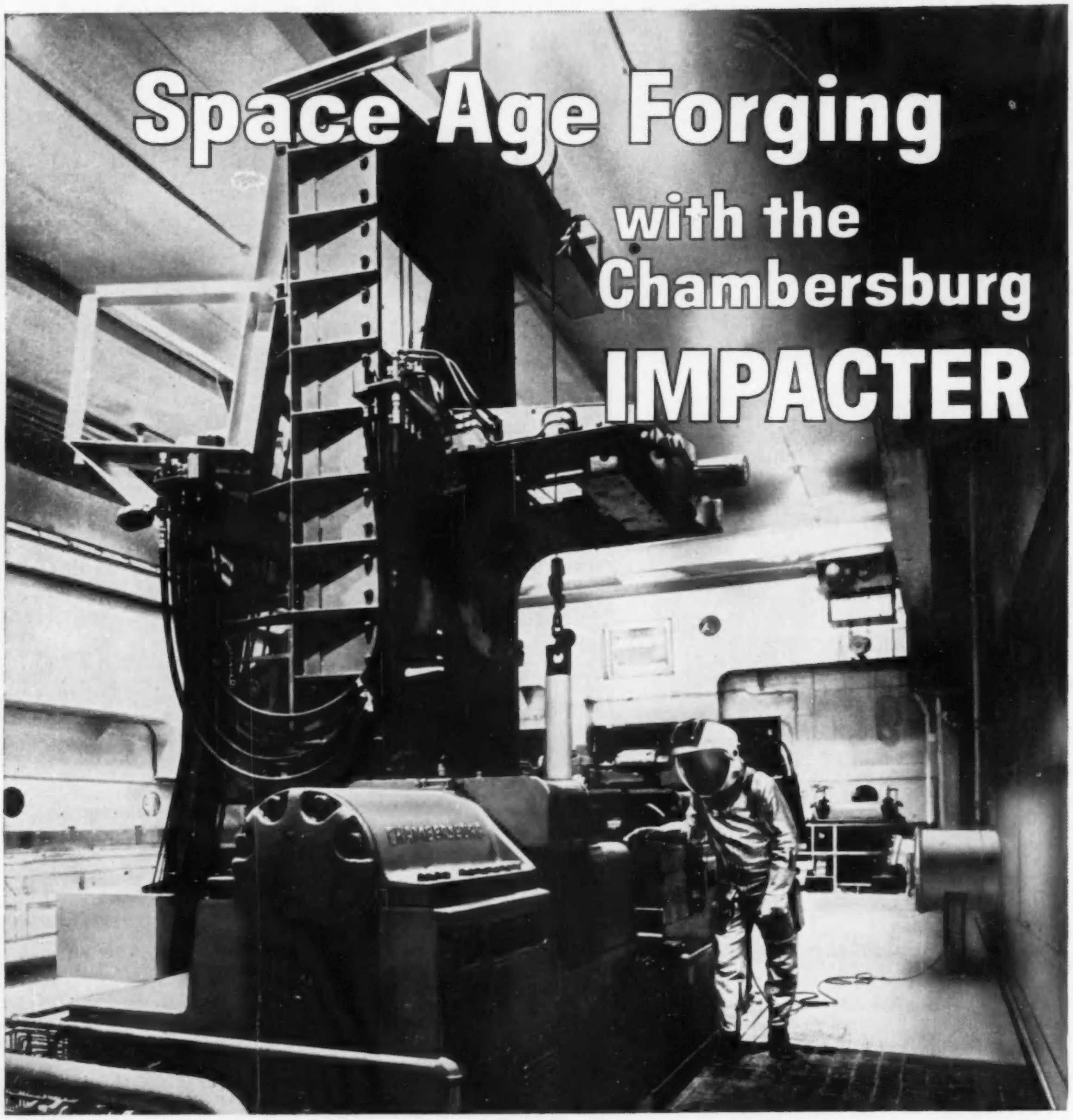
AUTOMOTIVE O.E.M.

Dayton Industrial Products Co.

A Division of Dayco Corporation (formerly Dayton Rubber)

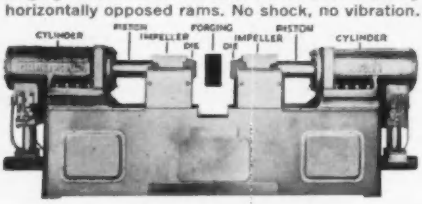
2001 Janice Ave., Melrose Park, Ill.

Telephone: TRinity 5-1620 New Center Bldg., Detroit, Michigan



Today's forging problems will not be solved with yesterday's forging equipment

THE IMPACTER: Designed and built by Chambersburg, pioneers in the development of machinery for forming metals by impact. In this revolutionary forging tool, the stock is struck from both sides by horizontally opposed rams. No shock, no vibration.



At the amazing new InFab project of Universal-Cyclops at Bridgeville, Pa., a Chambersburg Impacter is employed to forge ingots of molybdenum and other "exotic" metals in an atmosphere of pure argon gas, in which the workers have to wear space suits. The Impacter was selected primarily because of its instantaneous impact. At temperatures up to 4500° F, the Impacter strikes the ingot on two sides with 15,000 ft. lbs. of force; yet the impact is instantaneous and the transmission of heat to the die faces momentary. Other advantages are the Impacter's lack of shock or vibration, necessitating no heavy foundations, and the thorough working of the metal, deformation taking place equally on both sides. Learn more about this modern method of forging. Write today to Chambersburg Engineering Company, Chambersburg, Pa.

CHAMBERSBURG

DESIGNERS AND MANUFACTURERS OF THE IMPACTER

SAE JOURNAL

For Sake of Argument

When to Stop Thinking . . .

THE RIGHT TIME TO JELL an idea or a design depends on timing, on the idea, and on the environment in which it is expected to perform.

Much may be learned from the transport pilot's use of a flight plan.

Some executives and designers go over and over the same sets of data without ever forming thoughts into cohesive decision. The longer they think, the more undecided they seem to get.

The fast-decider is at the other end of the scale. He takes one quick, comprehensive look at the data, narrows his eyes for a moment, then says: "Let's do it this way."

Most of us are somewhere between these extremes. Like the transport pilot, we start by getting a flight plan. We focus the idea or design in our own minds. Then, like the pilot with the transport, we move into the environment where the idea is to perform.

We expose it to people and to physical tests. Often we run into storm clouds not provided for by the original flight plan. . . . So we alter our course — and readjust the original flight plan as necessary.

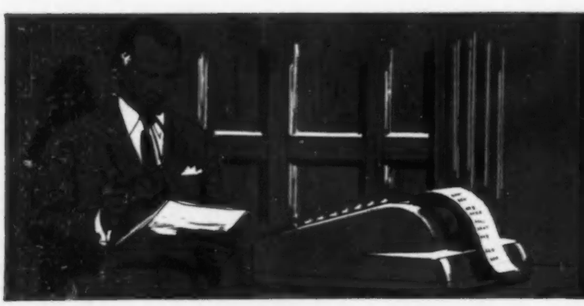
Each of us has to learn from experience as well as from flight plans.

But once we've contemplated carefully all the existing facts about a given idea and its environment, it's good to remember:

"No idea or design is worth a hoot until it has been jelled for use."

Norman G. Shidle


TRUCK WEIGHING STATION




STOP

chips

from SAE meetings, members, and committees

OUR USE OF MECHANICAL ENERGY, it is estimated, has multiplied 185 times in 10 decades. Machines now do 99% of the work in this country, while in the 1850's only about 35% of all work in the U. S. was accomplished by machines. The rest was done by men, women, children, and draft animals.

SOME TURBOJET ENGINES WITHSTAND SUBMERSION in salt water very well. These are the turbojets used in target drones. Some of these engines have fallen with the target into salt water and then been recovered and reused as many as 12 times. These engines sometimes are submerged several hours in the water before they are recovered and wait several more hours before they are cleaned.

SCALE MODEL SOLID PROPELLANT ROCKET CASINGS are being fabricated from strip steel in the 350,000 psi range. These cases have withstood hoop stresses of up to 309,000 psi. Full scale chambers are currently in the testing stage.

SHORT ROUTES DOMINATE the world's passenger traffic. More than half of the world's passengers travel distances of less than 500 miles, according to Sir George R. Edwards, managing director of Vickers-Armstrongs Ltd.

MOBILE ROBOT FOR RADIOACTIVE AREAS — Hughes Aircraft has developed a mobile robot for intricate, precise handwork and heavy material handling in radioactive areas.

The robot has closed circuit TV eyes, hydraulic muscles, handling arms capable of lifting 150 lb, and lift platform with a capacity of 1500 lb. It has a vertical reach of 10 ft, a horizontal reach of 3 ft. It is controlled through a long cable, and weighs 4500 lb.

FUEL LOAD of the DC-8 at maximum gross weight is 17,600 gal of kerosene or 118,000 lb. Thus fuel load approximates the total weight of the DC-7.

THE NORMAL LIFE OF AN AUTOMOBILE is estimated at 12–13 yr by the manufacturers. It varies from year to year. The life of cars was longer during the war years than at other times.

EXPLORING THE USE OF SOLAR-ELECTRIC SYSTEMS for producing energy to power automobiles, tractors, and the like are several industrial research laboratories. The possibilities for such applications are said to appear very attractive.

HEAT ABSORBED BY B-70 FUEL during its supersonic design mission is enough to heat 100 3-bedroom homes for a period of 40 hr. In order to provide sufficient cooling for crew and supporting subsystems , the pressurizing and cooling subsystem be- to approximately 120 large home ing developed has a capacity equal refrigerators.

TO **LOOK** is one thing.

TO **SEE** what you **look** at is another.

TO **UNDERSTAND** what you **see** is a third.

TO **LEARN** from what you understand is still something else.

BUT **TO ACT** on what you **learn** is all that really matters.

WITH LIQUID PROPELLANT ROCKETS there is a trend toward increased consideration of storable propellants.

AVERAGE INVESTMENT per farm in the United States will be more than $80,000 by 1975 — about double the amount needed today. This includes cost of real estate, livestock, and machinery.

Space-Age Dictionary —

AERONOMY, the physics and chemistry of the atmosphere at high altitudes.

THE SOVIET UNION CLAIMS to have the largest network of internal air communications routes in the world. They also have the biggest interior of any country in the world. But Aeroflot — the official airline — does not fly as many passengers as many scheduled airline-miles as do the airlines of the United States.

ONE NEW U. S. BOMBER will be able to deliver more payload and do more damage on one mission than did all the Allies' bombers during World War II.

PRESENT DEBITS AND FUTURE CREDITS
OF
COMPACT CAR PART-THROTTLE ENGINE FUEL ECONOMY

The "perfect" compact car at 40 mph,
with 100% thermal efficiency, would give 154 mpg.

	Estimate of Current Losses		Speculation of Loss Recovery	
	Thermal Efficiency, %	Mpg	Thermal Efficiency, %	Mpg
Available Energy	-40.0	- 61.6	+ 8	+12
Heat Energy Conversion:				
Dissociation	-14.0	-21.6	+11	+17
Delayed Burning	- 4.5	- 6.9	+ 4	+ 6
Combustion Heat Loss	- 6.0	- 9.2		
Incomplete Combustion	- 1.5	- 2.3	+ 1	+ 1.5
Total	-26.0	- 40.0		
Pumping Losses	- 5.5	- 8.5	+ 4	+ 6
Mechanical Friction:				
Pistons and Rings	- 3.3	- 5.1	+ 2	+ 3
Rods and Bearings	- 0.6	- 1.0		
Valve Gear	- 0.6	- 1.0		
Pumps	- 0.3	- 0.5		
Cooling Fan	- 0.2	- 0.3		
Total	- 5.0	- 7.9		
Tare Losses				
Fuel Handling:				
Carburetor Metering	- 0.2	- 0.3	+ 1	+ 1.5
Accelerator Pump	- 0.6	- 1.0		
Intake Manifold				
Distribution	- 0.4	- 0.6		
Vaporization	- 0.1	- 0.1		
Spark Advance:	- 0.3	- 0.5		
Total	- 1.6	- 2.5		
Total	-78.1	-120.5	+20*	+31*

*Total gain is reduced to compensate for cancelation effects.

Note: With frictionless drive train, present compact cars could get 34 mpg. This could be almost doubled—to 65 mpg—if concrete advances are made in all key loss areas of engine.

TABLE 1

If size, weight, and power of passenger cars are left alone, how is the engineer going to get better

FUEL ECONOMY

A look at the engine balance sheet shows where substantial future gains can be made in part-throttle fuel economy. Some of the traditional "economy villains" end up in last place when compared to other attackable losses in the engine.

Based on paper by

A. E. Cleveland and I. N. Bishop

Ford Motor Co.

STEPPING UP the part-throttle economy of a spark-ignition engine is really the art of cutting losses. To do this efficiently, the engineer must not only look for significant losses but ones that he can possibly do something about. To illustrate an engineer's attack on losses, a compact car, operating at 100% conversion of fuel into useful work and traveling at a road load of 40 mph, will be used as an example.

The "perfect" compact car would have a thermal efficiency of 100%. This would correspond to a fuel consumption of 154 mpg, as shown in Table 1. This is using all the fuel to drive the car through the air on a straight, smooth, level road. Although there are additional losses in the drive train and body of a real car, the examination of the engine can be used to demonstrate a method of improving part-throttle economy.

All the steady-state engine losses can be broken down into five groups:

- Availability — The heat energy that is available for work.
- Heat energy conversion — The losses incurred in turning the available heat energy into mechanical work.
- Pumping — The energy lost in moving the air and fuel in and out of the engine.
- Mechanical — Friction losses encountered from rubbing mechanical parts.
- Tare losses — Inefficiencies resulting from fuel handling and spark advance.

For each group of losses, there is also a possible chance of improvement, as shown in Table 1. It is here that the engineer must look to see where he can most profitably spend his time. Although the numbers are pure speculation for one example, they do point to trends that are common to all passenger cars.

Energy availability

The Carnot cycle efficiency places the maximum possible conversion of heat to work as

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1}$$

where:

T_1 = Maximum temperature in the cycle — about 1800 F for present engines

T_2 = Minimum temperature — about 60 F.

This results in a thermal efficiency of 77%. As long as a heat engine is used (as distinct from such power generators as fuel cells), this is theoretically the most mechanical energy available.

The next step is to choose from among the different heat engine cycles. In these are the well-known and much used diesel cycle, the recently discussed Stirling cycles, the Brayton cycle, known for its application to the gas turbine, and the last and most used, the otto cycle. The reasons for extensive use of the otto cycle are of a practical nature. From the theoretical efficiency calculations shown in Table 2, there are other cycles of equal or greater efficiency. However, the otto cycle gives a flexibility of operation under a wide variety of speed and load conditions, and a relative freedom from noise and vibra-

tion, that make it a leading contender in the passenger car field.

Using a compression ratio of about 10/1, the otto cycle gives a theoretical thermal efficiency of 60%. This is the first place that the engineer can cut into the losses, short of going to a different type of powerplant. An improvement of about 8% in thermal efficiency seems to be the outside limit for increasing compression ratio. This corresponds to a 19/1 compression ratio of an air standard otto cycle. Some recent laboratory tests only show about half this improvement in a test engine.

Heat energy conversion

Building an actual engine further compromises the available energy because burning at constant volume, no heat loss through cylinders, ideal working fluids, and complete combustion of fuel are only partially achieved. However, here the engineer has a chance to make continual improvements, which slowly add up to improved part-throttle fuel economy.

Table 2 — Heat Engine Cycles and Theoretical Efficiency

CYCLE	MAX EFFICIENCY FORMULA	USEABLE "R"	THEORETICAL EFFICIENCY
DIESEL	$E = 1 - \frac{1}{R^{K-1}}\left[\frac{r_c{}^K - 1}{K(r_c - 1)}\right]$	19:1	68%
OTTO	$E = 1 - \frac{1}{R^{K-1}}$	10:1	60%
BRAYTON 100% REGENERATION	$E = 1 - \frac{T_2}{T_1}(R)^{K-1}$	4	60%
BRAYTON 0 REGENERATION (JOULE CYCLE)	$E = 1 - \frac{1}{R^{\frac{K-1}{K}}}$	4	32.8%
CARNOT CYCLE OR STIRLING CYCLE WITH 100% REGENERATION	$E = \frac{T_1 - T_2}{T_1}$		77%

E = THERMAL EFFICIENCY
R = COMPRESSION OR EXPANSION RATIO
$K = \frac{C_p}{C_v}$ $\frac{\text{SPECIFIC HEAT AT CONSTANT VOLUME}}{\text{SPECIFIC HEAT AT CONSTANT PRESSURE}}$
T_1 = HIGHEST TEMPERATURE IN CYCLE °R = 2260 °R
T_2 = LOWEST TEMPERATURE IN CYCLE °R = 520 °R
$r_c = V_1 / V_2$ AT CONSTANT PRESSURE = 3

Note: Effect of dissociation is to change the specific heat at constant volume (C_v). Fuel-rich mixtures have high C_v's. This effect can be lessened by having excess air available at part-throttle engine loads.

Table 3 — Specific Heat (C_v) at Constant Volume

C_v	CONDITIONS
0.1715	AIR @ 540° R
0.185	AIR @ 1200° R
0.235	AIR @ 5000° R
0.282	FUEL AND AIR DURING *LEAN* MIXTURE COMBUSTION
0.296	FUEL AND AIR DURING *CORRECT* MIXTURE COMBUSTION
0.347	FUEL AND AIR DURING *RICH* MIXTURE COMBUSTION

Dissociation and Changes in Thermodynamic Characteristics of Working Gases — One of the largest losses and greatest potential gains is in the control of the properties of the working fluid. Dissociation is the mechanism that robs the combustion process of 14% of its thermal efficiency by forming new molecules. This is a partial reversal of the initial chemical reaction and the forming of intermediate products such as nitric oxides. Up to 11% of this loss could be recovered at part throttle by the addition of excess air.

Dissociation shows up as an apparent increase in the specific heat of the working fluid, and increasing temperatures accelerate the process. Table 3 shows the C_v effect for both air and different air-fuel mixtures. Since dropping cylinder temperature also drops the Carnot efficiency, the practical approach to keeping specific heats low is to burn lean mixtures at part throttle. Here, the diesel engine or a stratified charge engine has an advantage. The objective is to put as much excess air as possible into the cylinder and thus approach the specific heat of air.

Delayed Burning — Improved engine structures have greatly increased the usable rates of pressure rise in the cylinder, which points the way to smaller delayed burning losses. At present, a burning rate that generates a pressure rise of about 25–40 psi per crank angle degree is in general use. True constant-volume burning is possible, but the resultant rates of pressure rise react through the engine structure and produce engine harshness.

Allowing for improvement in the handling of high rates of pressure rise, about one-third of the present estimated 4½% thermal efficiency loss could be recovered by higher burning rates.

Combustion Heat Loss — Heat loss from the combustion chamber has probably been one of the most investigated subjects, and also probably the least productive of possible improvement. This is because only that heat lost at or very near top dead center of the piston stroke is worth the trouble of recovering. This is the only heat capable of doing its full share of work.

The ability to do work near top dead center is limited by the tolerance of the mechanism to the rate of pressure rise; so until we have been successful in raising this tolerance, there is little use in building heat dams or using high-temperature coolants.

The losses for the example engine turn out to be about 6% at 40 mph, as seen in Fig. 1. If there is steady improvement in usable rates of pressure rise, it could be expected that a maximum of 2% thermal efficiency could be saved. This estimate is further justified by Ricardo, who predicts that about one-tenth of the total 18–25% heat normally rejected to the cooling water from all sources could be transformed into useful mechanical work under the most ideal of circumstances.

Incomplete combustion — At road-load conditions, it is doubtful that the potential improvement in combustion thermal efficiency will exceed 1%. For the present example, it is estimated that the loss of thermal efficiency is 1.5%, although it may be higher in the full load or idle ranges.

One of the main ways to prevent incomplete combustion is to have an excess of air. This occurs with

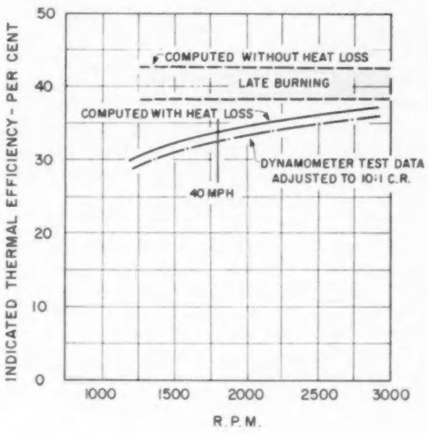


Fig. 1 — Loss in thermal efficiency of 6% results from heat loss through cylinder at 40-mph road load of compact car with 10/1 compression ratio.

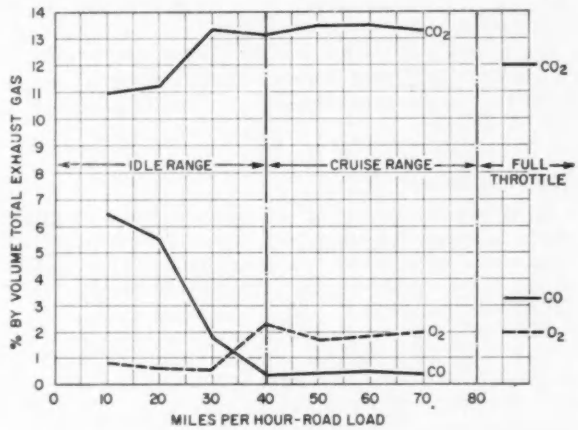


Fig. 2 — Exhaust gas analysis in cruise range shows that little unburned CO is ejected through exhaust valve. Data are for 352 cu in. engine, and curves are average of eight cylinders.

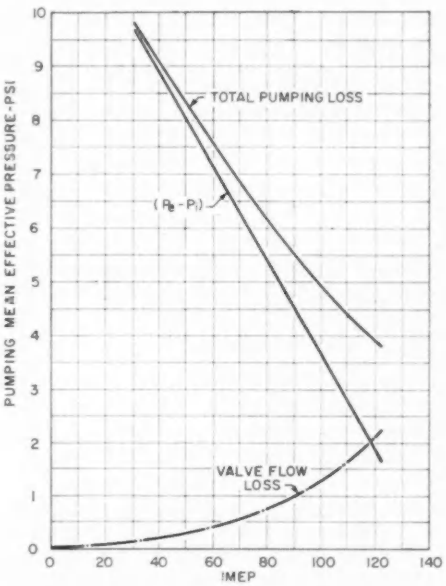


Fig. 3 — Throttle valve is main source of pumping losses at part throttle. $P_e - P_i$ on the graph represents the average pressure difference between exhaust and inlet manifold. Data are for 7/1 compression ratio engine operating at 1600 rpm.

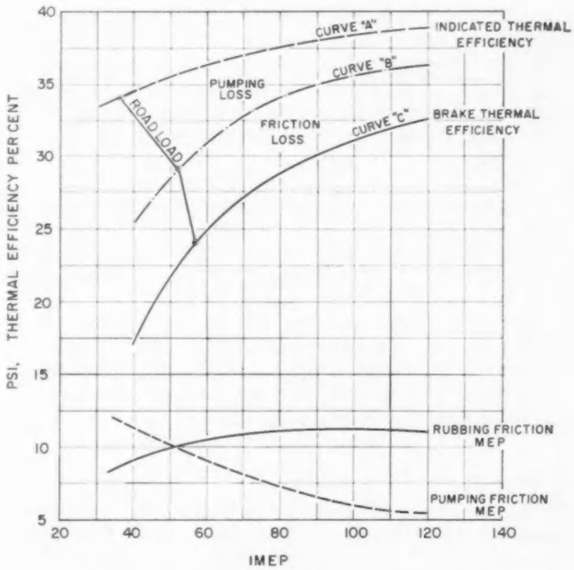


Fig. 4 — Friction and pumping loss for example compact car are shown. Compression ratio is 10/1 and engine speed is 1800 rpm.

FUEL ECONOMY

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lean part-throttle mixtures, while there are richer mixtures at the two ends of the driving range. The total effect is small, however, as shown in Fig. 2, when the constituents of the combustion gas at the exhaust valve are measured. Striking a rough average through the cruise range gives 0.4% CO by volume. This graph doesn't represent what is happening at top dead center, but it is the best that can be obtained at this time.

One other way to improve the conversion of CO to CO_2 would be to treat the wall of the cylinder to promote the reaction catalytically. This is probably a far-off solution.

Pumping losses

Moving gases in and out of the cylinder is another potential high improvement area for part-throttle operation. Of the 5.5% thermal efficiency loss in the example, 4% might be retrieved by the use of an unthrottled air charge.

The pumping loss can be considered in two parts; first, a function of the average difference in pressure between the intake and exhaust manifolds (P_e–P_i), and second, the valve flow loss, which represents the restrictions at the inlet and exhaust valves and reflects some of the losses in the combustion chamber and porting. In this manner of thinking, it becomes apparent that, as the load is reduced, the P_e–P_i loss will increase, and the flow loss will decrease. From Fig. 3, it's seen that the P_e–P_i loss climbs much more rapidly than the valve loss drops as the load is reduced. This pinpoints the throttle valve as the main source of pumping loss at part-throttle operation.

The 5.5% pumping loss is found from Fig. 4, which is plotted for the example compact car. The actual percentage of pumping loss would be somewhat larger than 5.5% if taken at the 40-mph point at fixed imep. However, the effective loss is minimized by the necessity of opening the throttle, and thereby diminishing the pumping loss as the efficiency becomes less. The possible 4% improvement in thermal efficiency comes from the cut in pumping loss which would be experienced by the example compact car with an unthrottled air charge at a road load point of 40 mph.

Cutting the other factors in pumping losses is more straightforward, but runs into many practical limitations. For example, mufflers have been improved over the past 10 years, but their effectiveness is still pretty much a function of back pressure, and decreases in P_e must usually be bought with increased noise — a compromise not too acceptable in the present passenger-car community.

Mechanical friction losses

Of the five main sources of friction losses, the pistons and rings have the lion's share of losses and, for that reason, potential gains. However, despite the well known role that friction plays in making mechanisms practical rather than ideal, the total losses for the example compact car are around 5% of the thermal efficiency.

Accurate estimates of mechanical friction are at best hard to come by since the common technique of motoring the engine also includes pumping losses. Thus, the percentage contribution of the main causes of friction (shown in Fig. 5) should be viewed as trends and order of magnitude. (The overall effects of rubbing friction are found in Fig. 4.)

An estimated gain in thermal efficiency of 2% is looked for mainly in the design of piston shapes. The trick is to contour a piston to provide the necessary close clearance (cold) to avoid piston slap while still retaining adequate oil film protection to avoid hot scuffing. The friction of piston rings is not expected to yield major gains since such gains are usually accompanied by the removal of one or more rings, and we're down to three rings now.

A few tenths of 1% thermal efficiency can be gained by using a lighter weight oil. Actually, rubbing friction is not metal-to-metal contact or the friction values would be much higher. It is largely an oil shearing friction. Fig. 6 points to about a half horsepower gain by going from an SAE 30 to an SAE 10W oil.

Another path to friction reduction is to increase the bore/stroke ratio. This effect is shown by a single-cylinder engine test in Fig. 7. However, although the piston velocities and distances traveled decrease as the first power of the length of stroke, the resulting decrease in friction horsepower is far less than this first-power relationship would indicate.

Tare losses

The handling of the fuel and the regulation of spark advance wind up the engine losses for steady-state road load . . . and offer the least potential savings in fuel economy. They also only cost about 1.5% in thermal efficiency for the example compact car.

Carburetor Metering — The carburetor is probably the most maligned component of any economy investigation. However, there is surprisingly little to be gained in further development of a well-designed carburetor.

Experience has shown that best economy at part-throttle is about 0.6 in. Hg below the manifold vacuum, which gives the leanest mixture for best torque. This is approximately the front edge of the fishhook curves, which are constant rpm curves plotted on a manifold vacuum — fuel flow graph. When this best part-throttle economy criteria, are used, the performance of two typical production carburetors are plotted in Fig. 8. At 40 mph, the poorest carburetor sacrifices a thermal efficiency of 0.2%.

Accelerator Pump — Getting fast engine reaction to throttle tromping now causes the highest fuel handling loss, about 0.6% thermal efficiency. This is also a high relative gain item since another way of doing the job of the accelerator pump, without loss of economy, may be found.

The actual loss depends on the type of driving, and shouldn't really be charged against our steady-state 40-mph compact car.

Intake Manifold Distribution — Within the practical limits of a well-designed manifold system, little

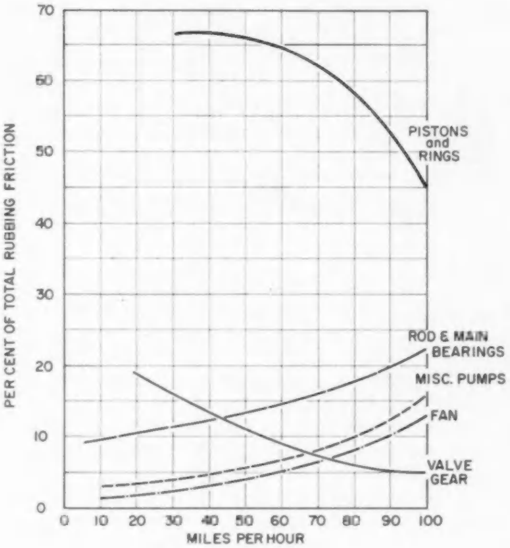

Fig. 5 — Percentage distribution of rubbing friction of typical engine at road load.

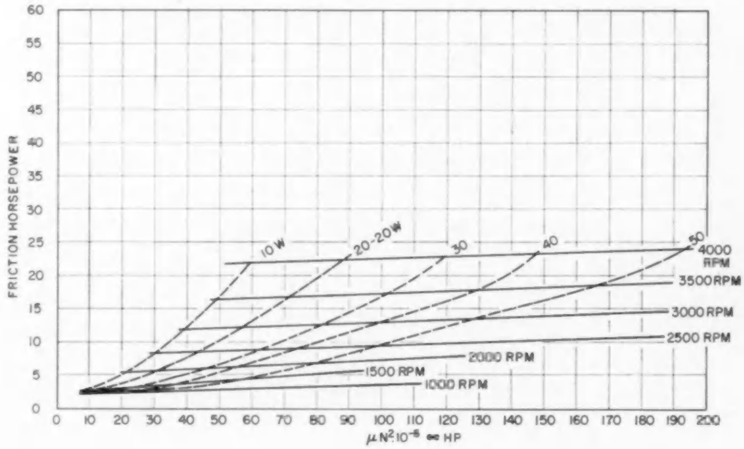

Fig. 6 — Effect of oil viscosity on engine friction for 6-cyl, 3.5 × 2.5 bore/stroke, 144.3 cu in. engine.

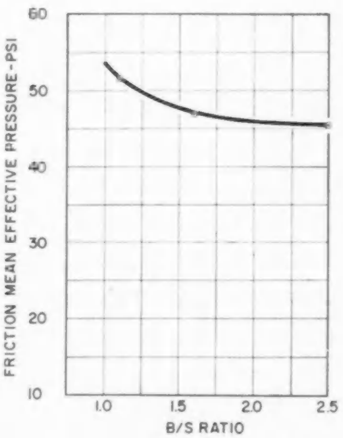

Fig. 7 — Effect of bore/stroke ratio on friction. Constant-displacement, 4000-rpm, single-cylinder engine.

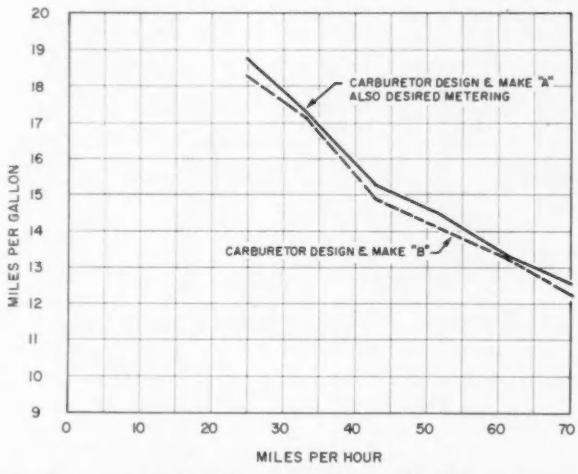

Fig. 8 — Comparison of production carburetors with desired performance shows little gain in economy is available from this source.

FUEL ECONOMY

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fuel is lost due to maldistribution. A reasonable average is about 0.4% thermal efficiency. A very small part of this loss may be recovered by fuel injection.

Vaporization — Little room for improvement is found in overall economy loss of 1/10 mpg levied against vaporization from fuel tank through the carburetor, and this estimate is for extreme conditions. Some of the factors that negatively influence this loss are:

- Near empty fuel tanks.
- High temperatures.
- Sustained high winds.
- Low boiling point fuels.
- High Reid vapor pressure fuels.

Spark Advance — Although a loss of 0.3% thermal efficiency might be found in the example compact car because of spark retard, this cannot be considered a pure loss. The interaction between compression ratio, octane number, and spark advance is complicated. It may well be found that a better overall efficiency results in increasing the compression ratio and retarding the spark, for a given octane-number fuel.

In the case of part-throttle or road load, the effect of spark advance is less dramatic than at full load, as seen in Fig. 9.

Summing up

When all the possible future gains are added up in Table 1, the total is less than the sum. This is because they are not altogether additive and, in some areas, previous gains are lost. Taking these cancelation effects into account, it still looks legitimate to add about another 20% to the thermal efficiency. This would make the compact car performance at the flywheel at 40 mph about 65 mpg.

If such advancement comes, no new carburetor, distributor, combustion chamber, or valve arrangement is going to produce an improvement of this magnitude. Rather, it will result from an evolutionary process of research in many diverse fields.

To Order Paper No. 150A . . .
from which material for this article was drawn, see p. 6.

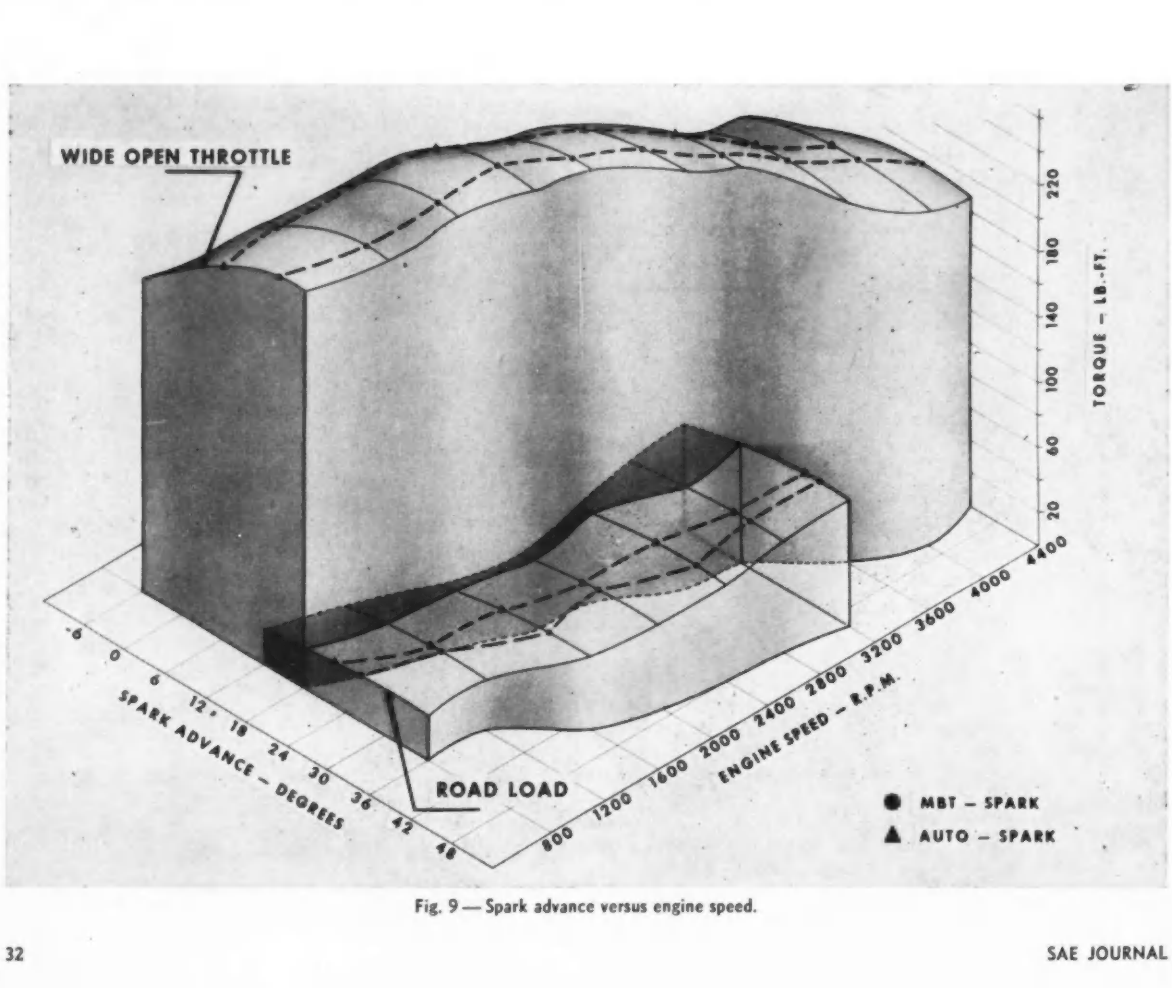

Fig. 9 — Spark advance versus engine speed.

designing with plastics for automotive applications

Material properties, end-product use, and environment must be carefully considered if plastics are to provide their optimum contribution to automotive applications

Based on report by

J. H. Crate and J. D. Young

E. I. du Pont de Nemours & Co.

THE importance of applying engineering design principles in developing new uses for plastics materials has not always been fully realized. Plastics are governed by the same physical laws and the same rules for good design as other materials. However, these principles can only be applied intelligently if data on pertinent properties of the material are available.

The properties to be considered and the values that should be used for these properties depend not only on the material, but also on the application itself. It is necessary to know or to have a reasonable estimate of what the end-product must do, and under what circumstances its function must be performed.

Temperature

The properties of plastics are of the same nature as those of metals differing only in their magnitude and the more pronounced effect of environment and loading. One important factor which has to be considered with all plastics is temperature. Fig. 1 shows the general relationship which exists between temperature and the strength and stiffness characteristics of plastic materials. At room temperatures, one set of property values would be used as the basis for design. As the end-use temperature increases, values representing the strength of the material at the higher temperature will have to be used. In this way, satisfactory performance under

designing with plastics

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the service temperature conditions can be assured. This change in strength occurs with metals too but we are not normally concerned with this change over the temperature range in which we are working.

Load duration

Another factor vital to proper plastic part design is the duration of the load that is applied. As before, this is a factor which is equally important in the design of metal parts but becomes significant with most metals only at much higher temperatures and longer periods of time.

Referring to Fig. 2, if a plastic part is loaded with a constant force F_o and allowed to deflect, the initial deflection is the strain which would be registered on a normal stress-strain curve. Thus, at time zero, the modulus value would be based on the initial deflection ΔL_o. After a period of time, additional deflection, which is sometimes referred to as creep or cold flow, would occur. If the sum $\Delta L(t)$ of the initial deflection plus the deflection due to creep is used as the basis for determining modulus, a value called apparent modulus can be obtained.

PLASTICS – types and processes

FUNDAMENTALLY, all plastics can be grouped into two classes; thermoplastic and thermosetting. Thermoplastic materials become soft when exposed to sufficient heat and harden when cooled, no matter how often the process is repeated. In this group fall the acrylics, the cellulosics, polyamides (nylon), polyethylenes, vinyls, acetal, and polycarbonates.

The plastic materials belonging to the thermosetting group are molded into a permanent shape when heat and pressure are applied to them during processing. Reheating will not soften these materials. The thermosetting plastics include the phenolics, the melamines and ureas, polyesters, and alkyds.

Thermoplastic materials are processed by injection molding, extrusion, blow molding, thermoforming, and other specialized techniques. In injection molding, the plastic material is put into a hopper which feeds into a heating chamber. A plunger then forces a plastic through this heating chamber where the material is softened to a fluid state. The fluid plastic then is forced by the plunger into a cool closed mold. When the plastic has cooled to a solid state, the mold opens and the finished piece is ejected from the press.

Extrusion is the method used to form thermoplastic materials into continuous sheeting, film, tubes, or profile shapes, and to coat wire and cable. In extrusion, the dry plastic material fed through a hopper into a long heating chamber through which it is moved by the action of a continuously revolving screw. At the end of this chamber, the molten plastic is forced through a die which imparts the shape desired in the finished product. The extrudate is then cooled to solidify the molten material.

Compression molding is the most common method of forming thermosetting materials. This process is simply the squeezing of the material into the desired shape by application of heat and pressure to the material in a mold.

Transfer molding, which is also widely used for thermosetting materials, is like compression molding in that the plastic is cured into an infusible state in a mold under heat and pressure. It differs from compression molding in that the plastic is heated to a point of temporary fluidity before it reaches the mold and is forced into the closed mold by means of a hydraulic plunger. Reinforced thermosetting materials may be processed by similar techniques or by hand lay-up, matched metal die, vacuum or pressure bag methods, or other special processes.

The apparent modulus is used as the basis of design to allow for the amount of deflection which will occur over a long period of time due to creep. Considering this in another way, if the part is loaded and kept under a constant strain, the force required to maintain this strain will decay. This force decay is referred to as relaxation. Modulus calculations made using the decayed force required to maintain constant strain after a period of time give apparent modulus values practically identical to those obtained in the creep test. Thus, the apparent modulus value could be utilized for design situations representing either circumstance.

Fig. 3 represents the apparent loss in strength and stiffness of a plastic material with time in accordance with the apparent modulus concept. Note that time is plotted on a logarithmic scale so that major deformation or relaxation occurs within the first few hours and diminishes as time increases. For example, with one engineering plastic, nylon, total deformation under load after 24 hr will be about 75% of that obtained in one year. Thus, where creep or stress relaxation should be considered in a plastic design, tests of relatively short duration can be used to accurately predict performance 1–10 years later.

Environment

A third important consideration in plastics design is the environment. Some plastics are affected by moisture and, upon moisture absorption, lose mechanical properties or change dimensions. With such materials, the properties of the plastic under the conditions of expected use should be taken into account during basic design work. Detailed data on the properties of these materials under varying conditions are available from manufacturers.

Other plastic materials are adversely affected by certain fuels, lubricants, or other substances used in passenger cars. Resistance of the plastic to such substances must be taken into account, and the correct material chosen for the job. Often, one

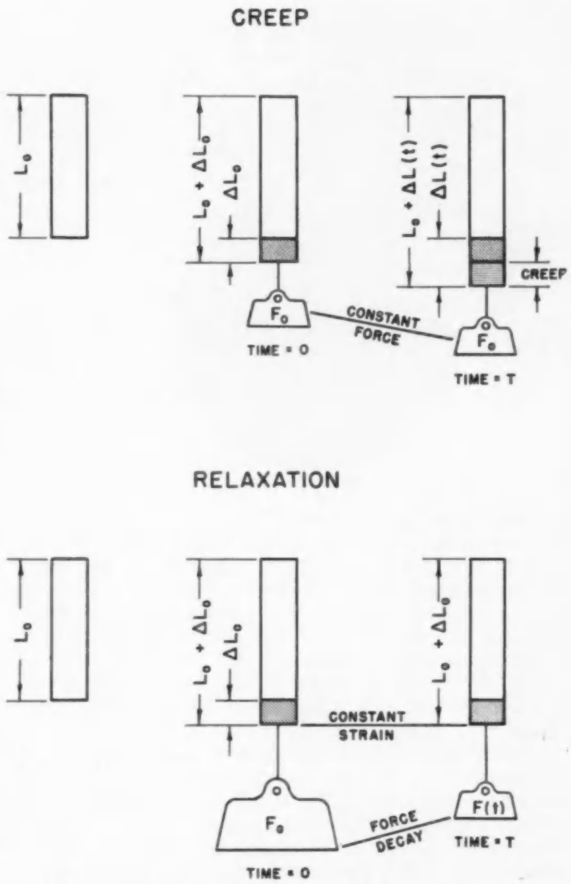

Fig. 2 — Creep and relaxation of a plastic part in tension.

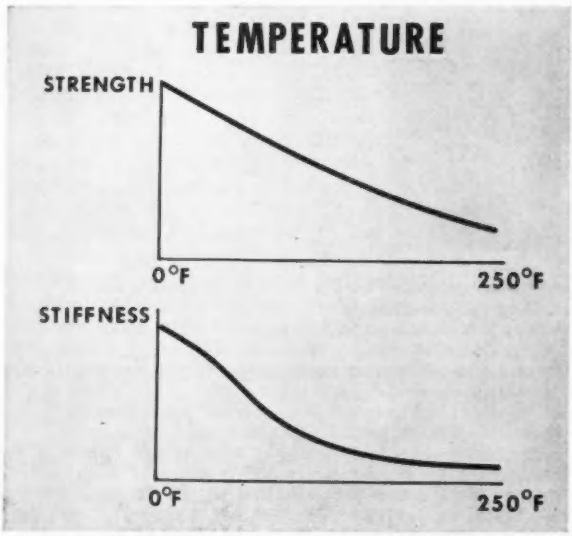

Fig. 1 — General relationship of temperature to strength and stiffness of plastic materials.

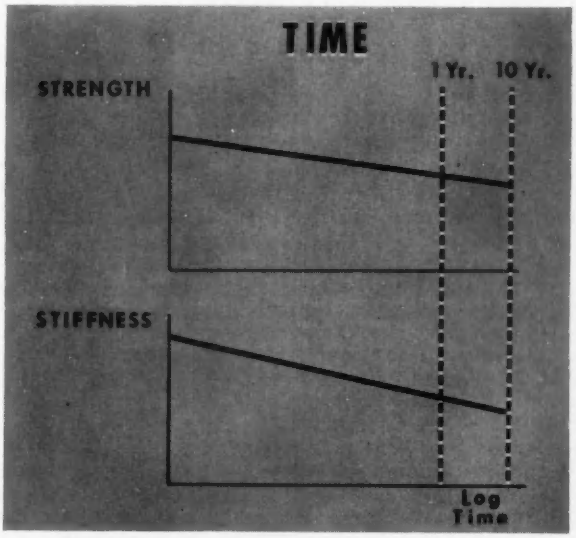

Fig. 3 — Apparent loss in strength and stiffness of a plastic material with time.

designing with plastics

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composition of a plastic family may be suitable while another of the same general class might not be suitable. Possible attack by agents with which the material will come into contact has to be considered over the range of temperatures which will be encountered. In many instances, final acceptance of a part designed to operate in contact with certain fluids will have to be made after thorough tests to insure its performance under all operating conditions.

Other factors which should be taken into account in general design with plastics are impact strength, notch sensitivity, fatigue characteristics (particularly important in gear design), optical properties, color and texture requirements, weatherability, and electrical properties. Subsequent articles in this series will discuss in more detail the treatment of these factors in plastic design.

With regard to dimensions of plastic parts, all plastic materials exhibit a higher coefficient of thermal expansion than metals. When plastic parts are used in conjunction with metal parts this differential in thermal expansion must be taken into account. Elongated mounting holes or elastomeric grommets to allow for movement are techniques which have been used to overcome this problem. Many solutions to this difficulty can also be found through basic design of the component.

Specifications

Once a plastic part has been suitably designed and tested for production, it is important that adequate specifications be written to insure that the part as purchased for production will serve the purpose for which it was designed. The scope of the specification will depend on the performance required of the part. In general, as the specification becomes more complex, the cost of the part increases. Consequently, the best specification covers the critical needs of the application and omits the nonessential requirements.

Specifications prepared by an end-user are directed at two suppliers, the resin supplier and the processor. The specification should require that the resin supplier provide the proper material with a quality which meets minimum standards and that the processor shape the resin according to the design so that it meets the performance requirements of the part. Thus, meaningful specifications should cover the best resin, the part design, and the performance of the part. Materials and design engineers, quality control groups, and purchasing agents are devoting more and more attention to this important factor in the use of plastic parts in the automotive industry.

With the newer plastic materials being offered today with improved properties in the areas of strength, stiffness, toughness, abrasion resistance, lightness in weight, corrosion resistance, and the opportunities for cost savings through raw material costs and processing economies, the design

J.H. Crate

Dr. J. D. Young

J. H. Crate joined du Pont in 1953 as a member of the Sales Promotion Section, and was transferred to the Technical Services Section where he has been working on a variety of plastics design problems for over four years. He was recently promoted to Design Consultant at the Sales Service Laboratory.

Dr. J. D. Young did research for the War Production Board Rubber Program on preparation of new synthetic rubbers while working for his Ph.D. in Organic Chemistry at the University of Illinois. He has been employed by du Pont since graduation in 1947 in various capacities in sales and development. Young's association with the automotive industry began in 1951, working first on automotive antifreezes and other chemicals, and in recent years, on plastic material developments. He is presently Manager of Automotive Development for the Polychemicals Department, and in this capacity is concerned with the development of engineering applications for du Pont plastics. Dr. Young is chairman of the Plastics Subcommittee of the Engineering Materials Activity Committee of SAE.

engineer has an almost unlimited opportunity for proper application of these materials to solve his day-by-day design problems. Subsequent articles in this series will illustrate in more detail how other engineers have capitalized on the unique qualities of this class of engineering materials.

The use of plastic materials by U.S. industry . . .

. . . has grown since 1946 from 400 million pounds annually to over two billion pounds per year in 1959. This fivefold increase has also been reflected in the increased use of plastics by automotive design engineers. The estimated use of plastics in the average 1954 car was about 10 lb. This grew in the 1959 car to about 25 lb and it has been predicted that by 1970 the average per-car consumption of plastic materials will reach 50 lb or more.

This growth is indicative of the fact that plastics are being recognized as engineering materials in their own right, and are no longer being looked upon as merely substitutes for some other material. The continued success of plastics in the automotive industry depends directly on the use of proper design principles in their applications. The mere substitution of a plastic material for another material in an existing design will almost preclude the success of the application since properties of the two materials involved are quite different. By considering the properties of the particular plastic from the beginning and designing the component to capitalize on the unique combination of properties which are usually available, the design engineer can produce components offering functional advantages, weight savings, and costs economies.

Recognizing the increased interest in plastics as engineering materials, the Plastics Subcommittee of the Engineering Materials Activity Committee of the Society of Automotive Engineers, in cooperation with the Professional Activities Group on Plastics in the Automotive Industry of the Society of Plastic Engineers, is sponsoring a series of articles on plastics in the SAE Journal. This series will discuss the various types of materials available today, and through suitable examples of parts now in production, illustrate the basic design principles which were utilized to advantage.

All six articles in this series will be available in approximately six months as SP-184 at $1.50 to members and $3.00 to nonmem-members. **To order SP-184, see page 6.**

Locomotive Gas Turbine Developed in Sweden

Based on paper by

L. H. Tengner

Aktiebolaget Gotaverken, Goteborg, Sweden

A GAS TURBINE locomotive which delivers 1000 hp at the wheel rims, has a maximum tractive effort of about 30,000 lb, and a top speed of 56 mph, has been developed by Aktiebolaget Gotaverken for use where traffic volume does not justify electrification.

The gas turbine is fed from a gas generator which is a 2-stroke, opposed-piston engine with reciprocating compressors. The compressor pistons are crank-bound, which means that the dead centers of the pistons are fixed. This design makes possible using a clearance of only 5/64 in. between the compressor piston and compressor cover, thus insuring a small clearance volume and high volumetric efficiency.

Free-Piston versus Crank-Bound

The clearance between piston and cover in the free-piston gas-generator can never be kept at such small values for reasons of safety, and volumetric efficiencies are thus much lower. With increased load, the free pistons are working closer to their outer positions. The clearance volume of the compressors is then the largest and the efficiency the least at the moment when the requirements for combustion air and compressor efficiency are at their maximum.

On the other hand, the binding of the working pistons to a crankshaft would give a constant compression ratio in the working cylinder which can not be reduced below a certain value with a guarantee of cold starting. With increasing load and scavenge air pressure both compression and combustion pressures would rise to values intolerable in a diesel cylinder. To avoid this the gas generators are equipped with a compression regulator which changes the compression ratio to correspond with the load and so achieves a substantially constant combustion pressure over the main part of the load range.

To Order Paper No. 214C . . .
from which material for this article was drawn, see p. 6.

X-15 Controlled in space by

Flight simulation studies show that pilot can

Based on paper by

George B. Merrick

North American Aviation, Inc.

ANGULAR ACCELERATION of the X-15 research vehicle will be controlled in space by a reaction control system which depends on direct pilot control. This system will help make possible the altitudes and speeds shown in Fig. 1.

Reaction control rockets, driven by hydrogen peroxide, are located in the nose for pitch and yaw, and at the wing tips for roll (Fig. 2). Two independent systems are provided, either of which is adequate for control. To obtain accelerations, eight 113-lb-thrust rockets are used in the nose, and the two 40-lb-thrust rockets are used in each wing tip.

Reaction control inputs are applied through a control handle. This controller provides all three control inputs — pitch, roll and yaw — proportionally as a function of controller deflection.

Fig. 3 shows the pitch and yaw system. Mechanical linkages connect the control handle to propellant metering valves, which are stainless steel spool and sleeve arrangements. These valves meter flow of the hydrogen peroxide to the nozzles in the nose of the aircraft.

Fig. 4 shows the propellant supply system schematic. Helium is used to pressurize all source tanks. Here the helium source is shown with pressure regulation from 3600 to 500 psi. A special expulsion bladder provides positive expulsion for any load factor. An independent propellant source provides hydrogen peroxide for each group of reaction nozzles and one of the auxiliary power units.

DEVELOPMENT PROGRAM of the X-15 will be delayed about six weeks, according to news reports, because of the recent explosion that severely damaged X-15 No. 1. From the reports it appears that the explosion was probably caused, not by a structural fault, but by fuel leakage or a spark.

Flight control simulation

Fig. 5 shows a typical simulation flight of a high-altitude mission. Flight began at drop conditions of Mach 0.8 at approximately 40,000 ft. At this point thrust was on and the pilot made an abrupt pull-up 15 deg angle of attack until the proper initial climb angle was established . . . 50 deg for this mission.

At that point a zero G trajectory was maintained throughout the exit phase. This technique provides control of the exit path by establishing the initial trajectory angle, altitude and speed.

During burning, pitch and yaw control was required to correct for thrust malalignment. Burnout occurs at approximately 90 sec from drop as shown at a velocity of 6200 fps and at 160,000 ft. At this point the effects of thrust malalignment are seen in the oscillations in angle of attack and sideslip.

At burnout the pilot began use of the reaction control system and this system was used throughout the rest of the high-altitude phase to maintain angle of attack and sideslip zero.

Peak altitude reached was slightly over 250,000 ft. Recovery used for this particular flight was a 15 deg angle of attack established at approximately 200,000 ft on the way down. Required stabilizer trim for this angle of attack can be set in any time near peak altitude and the reaction control system is used to establish this angle of attack. As the dynamic pressure builds up at re-entry at approximately 150,000 ft, the load factor builds up and for this mission the pilot allowed the load factor to in-

Material drawn from an
SAE Metropolitan Section paper

reaction-control rocket system

control angular acceleration directly.

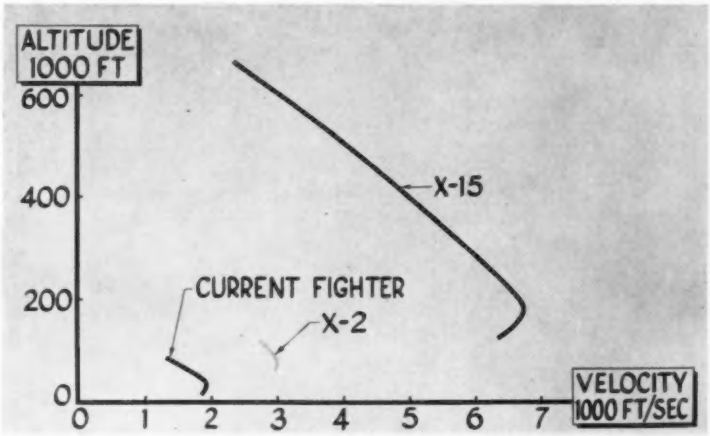

Fig. 1—X-15 performance compared with current manned Fighter.

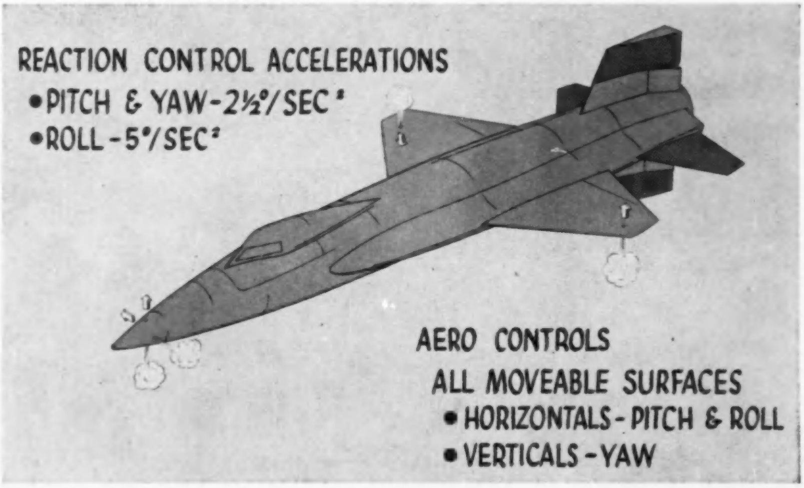

Fig. 2—X-15 flight controls.

X-15 reaction-control rocket system

. . . continued

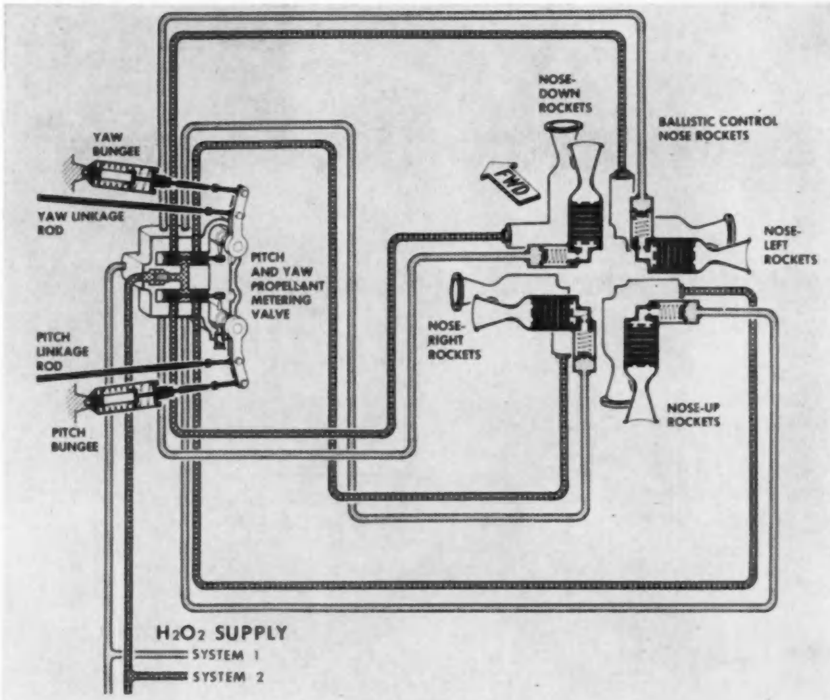

Fig. 3 — Pitch and yaw reaction control schematic.

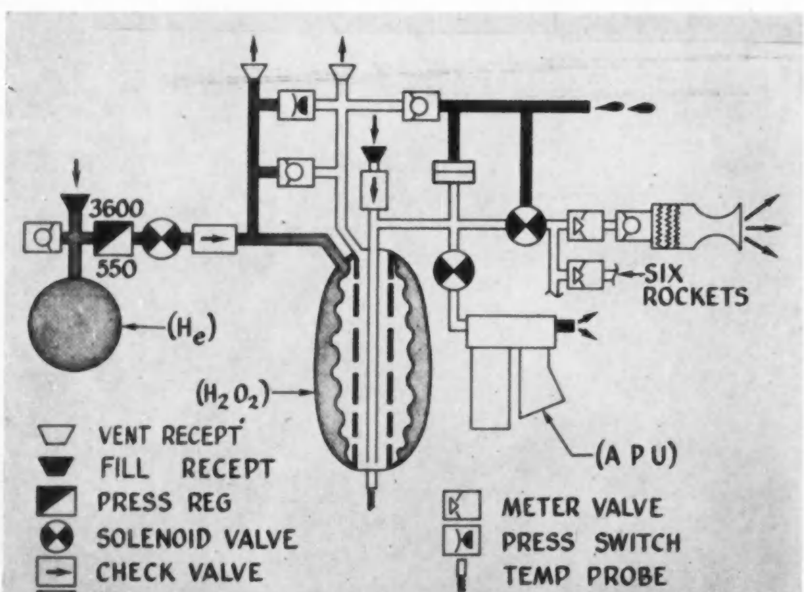

Fig. 4 — Propellant supply system.

crease to 5 g's and then maintained this 5 g recovery until completion of pullout.

These studies have shown no specific augmentation for the reaction control system was necessary — that is, the pilot controls angular acceleration directly. On reentry, the reaction control system is effective down to approximately 180,000 ft or a dynamic pressure of 25 psf at which time the effectiveness of both the reaction control system and the aerodynamic control system are approximately equal. Change-over is made at the convenience of the pilot and has not been found to be particularly critical.

Fig. 6 shows the effects of time spent in the flight control simulator. The pilot's first and seventh run are shown indicating a marked improvement in control accuracy and amount of control power used. (Angle of attack and reaction control input are plotted as a function of time.) The first run required approximately 2000 lb-sec, the seventh run used only 500 lb-sec. Over 10,000 lb-sec are available for control.

Currently a complete reaction control system test set-up is in operation at Edwards Air Force Base. Preliminary test data have shown the rapid response provided by a typical motor. Simulator studies have shown that lags on the order of ½–1 sec are tolerable.

One problem has been found with propellant temperature in that if the system is at too low a temperature, consistent motor starts are very difficult to obtain. To eliminate this problem, a heater system is used which elevates and maintains an acceptable temperature in the supply, propellant lines, and the motors themselves.

To Order Paper No. S247 . . .
from which material for this article was drawn, see p. 6.

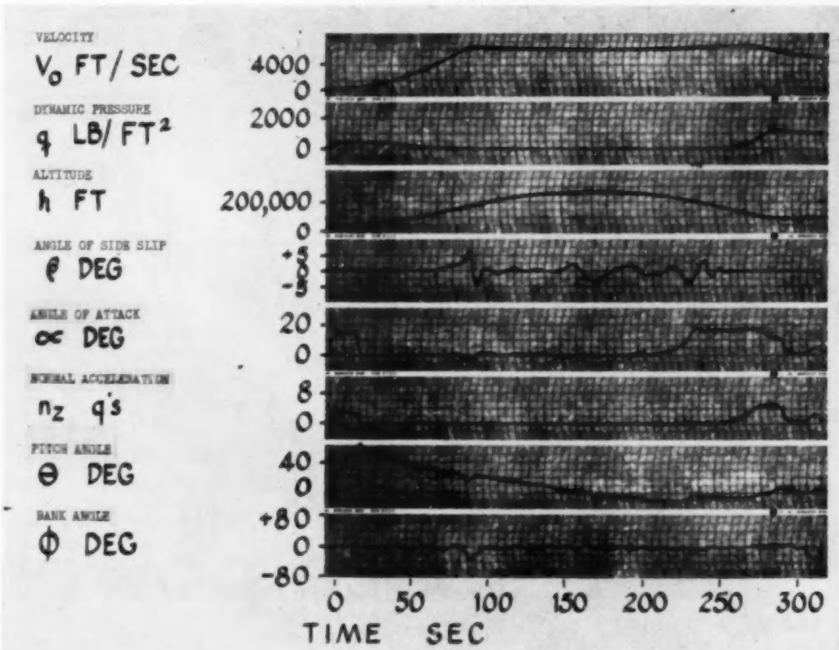

Fig. 5 — Simulation flight of high-altitude mission.

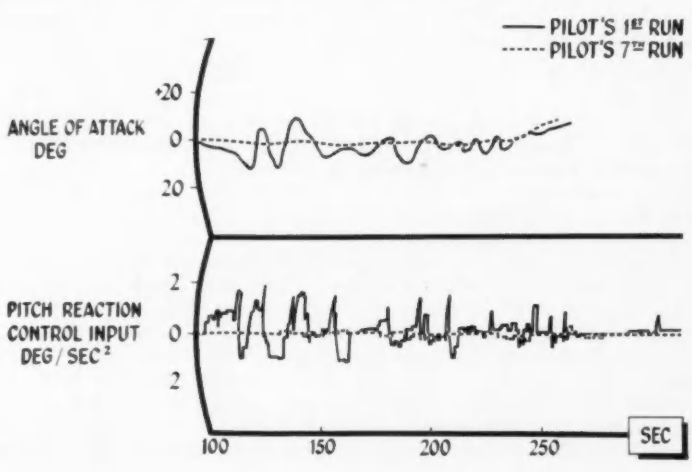

Fig. 6 — Effects of time spent in flight control simulator during a 250,000-ft mission.

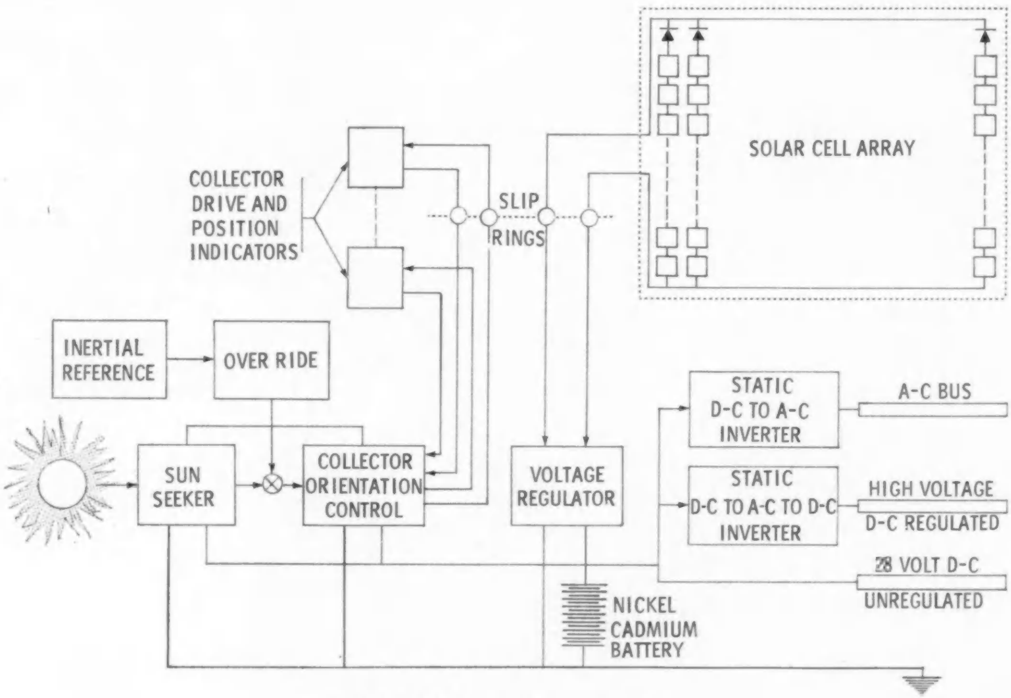

Fig. 1 — Solar-photovoltaic power system.

How silicon solar cells rate for space power

Based on paper by

E. T. Raymond

Boeing Airplane Co.

CONVERSION of solar radiant energy to electric power by a semiconductor device such as the silicon solar cell is one of the most attractive sources of power being considered for long-duration space vehicles. Systems using the photovoltaic process are made up of a group of devices, such as the silicon cell, that will provide enough power while the vehicle is in sunlight to handle operating-equipment loads and at the same time charge storage batteries to take care of required dark-side power. An orientation system also is included to obtain maximum cell output. Fig. 1 is a simplified diagram of such a system.

Systems that depend on silicon cells as a primary energy-conversion device possess a number of advantages that, to date, make then the best available in the solar-power field. Some of the most important are:

1. Silicon solar-cell systems are now being used successfully in space satellites; thus, they are the only proved long-operating-time power equipment available now for space use.

2. The weight of a solar-cell system does not increase with mission time; that is, no unexpendable fuel is required to support it.

3. A photovoltaic system now has a higher overall efficiency (10%) than any other solar-power system by a factor of about 3/1. This means that the solar-cell array will require less area than competing solar-power system collectors. (Actually, it appears that 15% efficiency can be obtained in the near future.)

4. To perform efficiently, a solar cell must face

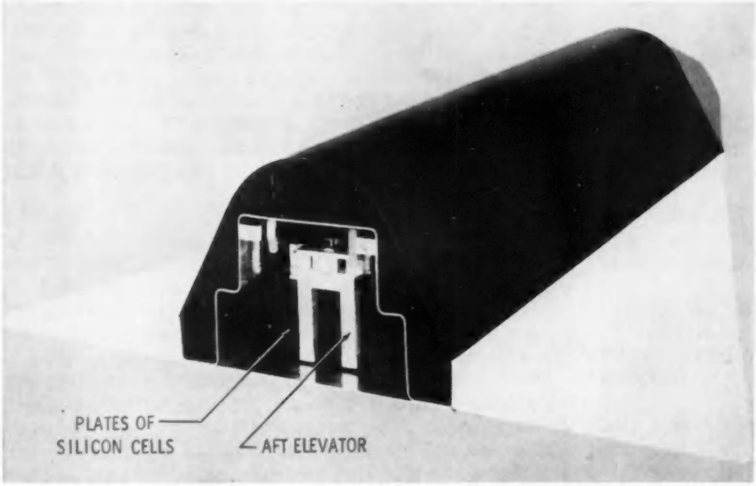

Fig. 2 — Model of silicon-cell solar collector in retracted position.

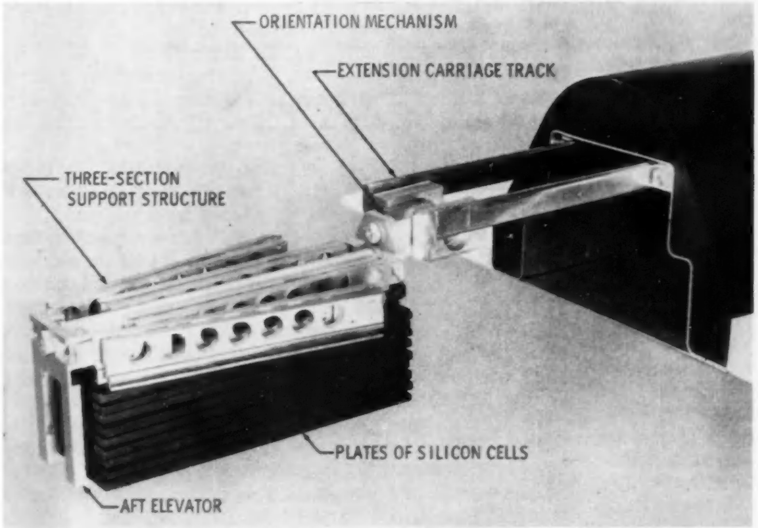

Fig. 3 — Model of silicon-cell solar collector in initial deployed position.

the sun. However, its output drops off in a cosine function, which means that orientation accuracies on the order of 15 deg will be adequate for this equipment. In the case of competing solar-power devices, orientation accuracies of 0.5 deg or even as close as 0.1 deg may be needed. In addition, a flat cell array can be used, which is not nearly as precise a configuration as the mirrors, or parabolic or cylindrical collectors used by other power-conversion techniques.

5. The solar-cell power system requires no moving parts to accomplish its conversion function. Therefore, it has a high reliability potential.

6. Photovoltaic devices do not require a separate radiator to provide a sink for heat rejected by a power cycle.

On the flip side of the record, however, there are sufficient disadvantages in solar-cell equipment to warrant interest in other solar energy conversion methods. Some of these disadvantages are:

1. Individual solar cells cannot be made in large sizes without a loss in efficiency, due to internal voltage loss. As a result, a cell array with a 1-kw output capability in sunlight will contain as many as 60,000 individual cells. This number may be raised by as much as 65% to provide extra power for dark-side storage. Each must be electrically connected to the power-distribution system and each connection is a possible failure point. In a large solar-cell array which must be folded, these connections may degrade the inherent reliability of this static system.

2. Photovoltaic cell arrays must be stored and protected from launch and re-entry environment. This means that a vehicle dependent on silicon solar cells for power also must carry equipment that will provide required energy during launch and re-

silicon solar cells

. . . continued

entry. A lunar landing would probably be impractical with a cell array extended.

3. The large solar-cell array is susceptible to meteorite damage, is difficult to stow in the vehicle, and increases the aerodynamic drag of the vehicle at altitudes below 200 nautical miles.

4. The fixed weight of the system and its deployment equipment is rather high and does not decrease with time (as with an open-cycle chemically fueled APU system), thus posing possible re-entry problems.

5. The electrical loads applied must be matched carefully to cell impedance, a factor which complicates the design of other vehicle equipment.

Installation study

Figs. 2, 3, and 4 show an extension mechanism to deploy, orient, and retract a silicon cell collector from a hypothetical long-duration space vehicle. The silicon cells which are currently produced commercially have a rectangular shape of approximately 1×2 cm (0.39×0.79 in.) and a thickness of approximately 0.06 in. For this extension mechanism design, it has been assumed that a number of the individual silicon cells are connected together and mounted on 11 large plates. It is also assumed that the electrical energy generated on any one of the large plates of cells can be connected to the other large plates and to the vehicle by conventional wiring methods. Based on a predicted 10% efficiency of silicon cells, it is assumed that 440 sq ft of cells will produce 4.4 kw of electrical energy if the cells are properly oriented with respect to the sun.

In the stowed position, the 11 plates of silicon cells are installed in an elevator on the primary support structure. Four three-section support tubes are connected to the primary tube by hinges and folded along the sides of the primary support tube in the stowed position. Upon deployment they are extended by actuators or a cable system to be perpendicular to the primary support tube. Ten of the 11 plates of silicon cells are then extended on tracks on the three-section support tubes by a friction drive system or a cable system to array the silicon cells. The eleventh plate of cells could either be located in a fixed position at the end of the elevator or could be moved by the elevator to the center of the 10 extended plates to act as a spacer. The cells on the eleventh plate would be exposed to the sun in either position.

As shown in Fig. 3, the mechanism to orient the collector to the sun is at the forward end of the primary support tube. The trunnion allows 180 deg of motion in the vertical axis and 360 deg of motion in the longitudinal, with one orientation motor and gearbox to provide the power to position the collector in both axes of rotation.

It is estimated that this extension mechanism would weigh 610 lb with all possible structure made of aluminum. This weight includes an allowance of 127 lb for the silicon cells, but does not include the weight of electric wire to connect the individual cells or to connect the 11 plates of cells to each other or the vehicle. A corresponding weight of 502 lb has been estimated for this configuration with all possible structure made of magnesium.

This configuration would require 110 cu ft of storage compartment within the space vehicle or a ratio of 0.25 cu ft of storage volume per sq ft of deployed collector, and a ratio of 25 cu ft per kw of electric output.

A similar extension mechanism for 1080 sq ft of silicon cells mounted on 17 support plates to produce 10.8 kw of electrical energy was also designed.

It is estimated that this extension mechanism would weigh 1048 lb with all possible structure made of aluminum. The weight includes an allowance of 311 lb for the silicon cells but does not include the weight of electric wire to connect the individual cells or to connect the 17 plates of cells to each other or the vehicle. A corresponding weight of 853 lb has been estimated for this configuration with all possible structures made of magnesium.

This configuration would require 341 cu ft of storage compartment within the space vehicle or a ratio of 0.316 cu ft of storage volume per sq ft of deployed silicon cells, and a ratio of 32 cu ft per kw.

To Order Paper No. 154A . . .
from which material for this article was drawn, see p. 6.

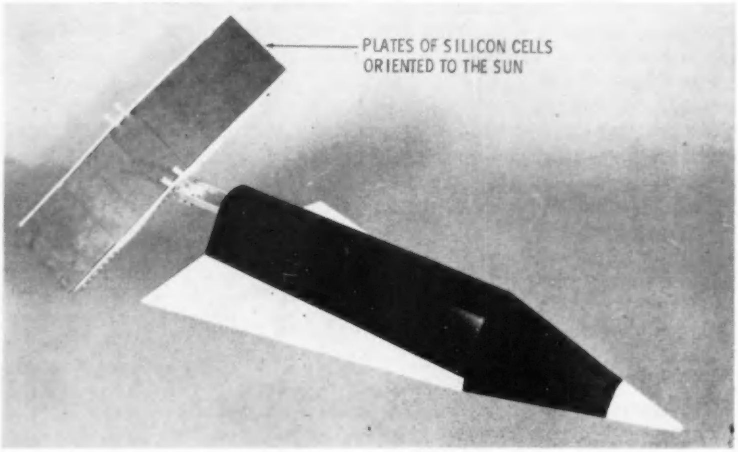

Fig. 4 — Model of silicon-cell solar collector in fully deployed position.

The next decade will see investigation of many of these

Energy conversion devices

ENERGY CONVERSION MATRIX covering most of the energy conversion devices that will be investigated in the next decade. (Taken from Proceedings of a Seminar on Advanced Energy Sources and Conversion Techniques, Vol. 1, p. 19) (Armed Services Technical Information Agency, No. AD 209301, Nov. 1958.)

	Potential		Kinetic			Electro-Magnetic	
			Directed	Directed / Random	Random		
To \ From	Chemical	Nuclear	Mechanical	Free Particle	Thermal	Electro-Magnetic Fields	Electro-Magnetic Circuits
Chemical	a) Exothermic and endothermic reactions, catalysis, etc.	a) Production of new elements by fission, fusion or radioactivity	a) Mechanical activation of chemical processes (e.g., solion)	a) Radiolysis (radiative dissociation)	a) Endothermic reactions b) Thermal dissociation	a) Photosynthesis b) Photochemistry c) Photogalvanic	a) Electrolysis b) Arc dissociation c) Association
Nuclear		a) Fission b) Fusion c) Radioactive isotopes d) Photodisintegration e) Nuclear bombardment		a) Fission b) Spallation c) Fusion d) Nuclear bombardment	a) Fusion processes b) Fission processes	a) Photodisintegration (γ-n, γ-p, γ-d, γ-t)	
Mechanical	a) Equilibrium volume and pressure processes		a) Compressors b) Compressed gas engines c) Mechanical couplings and gear trains d) Mass accelerators (propellers, etc.)	a) Ion propulsion b) Radiation sail	a) Positive displacement engines b) Turbines c) Thermal expansion of liquids and solids	a) Radiation turbines b) Radiation sail c) Electro-magnetic field reactions on on conductors	a) Vibrators b) Solenoids c) Motors d) Accelerators e) Magnetostriction
Free Particle		a) Radioactive emission b) Photodisintegration c) Nuclear bombardment	a) Mechanical spark generators	a) Secondary emission b) Fusion processes	a) Evaporation b) Thermionic emission c) Fusion processes d) Fission processes	a) Photoemission b) Volume photoelectric effect in gases c) Compton effect d) Exciton formation in insulators e) Photodisintegration	a) Field emission b) Accelerators
Thermal	a) Combustion b) Explosion c) Other exothermic reactions d) Catalysis	a) Fission b) Fusion c) Radioactive isotopes	a) Various mechanisms classified as friction b) Heat of compression	a) Atomic absorption b) Recombination c) Isotope devices	a) Heat exchangers b) Boilers c) Refrigerators	Direct Absorption by Matter a) Solar collectors b) Diathermic devices	a) Resistive heating b) Induction heating c) Ion gas generation d) Magnetohydrodynamics
Electro-Magnetic Fields	a) Chemiluminescence	a) Fission b) Fusion c) γ to radio d) Photonuclear reactions	a) Triboluminescence	a) Cosmic radiation b) Bremsstrahlung c) Cathode luminescence d) Fusion e) Nuclear bombardment	a) Black body emission b) Grey body emission c) Spectrally selective emission d) Thermoluminescence	a) Rayleigh scattering b) Raman scattering c) Resonance fluorescence d) Photoluminescence e) Stokes and anti-stokes fluorescence f) Optical systems g) Polarization h) Frequency transformers	a) Electromagnetic radiation, transmitters, antenna b) X-rays c) Light (fluorescence) d) Klystron, magnetron e) Electroluminescence
Electro-Magnetic Circuits	a) Fuel cell b) Battery c) Ion permeable membrances	a) Radioisotope electrostatic generators b) Fusion	a) Generators b) Accelerators c) Electrostatic devices d) Piezo-electric devices e) Magnetostriction	a) Thermal (isotope) batteries b) Electron voltaic effect c) Secondary emission	a) Thermopiles b) Thermionic emission devices c) Workman-Reynolds effect d) Thermomagnetics e) Pyro-electricity	a) Photoelectric devices b) Photogalvanic devices c) Antennae d) Interaction between fields and conductors	a) Inverters b) Transformers, solenoids, magnetic circuits c) Rectifiers

Chart presented by Lt.-Com. Frank W. Anders, U. S. Navy Bureau of Ships in Paper No. 159A. To order this paper, turn to p. 6.

Design for minimum corrosion

Based on paper by

Allen M. Montgomery

Alcoa Research Laboratories, Aluminum Co. of America

WAYS TO KEEP CORROSION to a minimum in engines combining aluminum and cast-iron components are revealed by recent Aluminum Co. of America researches. *All*-aluminum engines, the tests show, are free of potential galvanic corrosion and essentially free from corrosion in general. The tests dealt with liquid-cooled engines and with cast-aluminum-alloy parts that are in direct contact with the coolant . . . because no serious corrosion problems seem to exist as regards other components of such engines.

It is general knowledge that copper is an alloying element that usually reduces the resistance to corrosion of cast-aluminum alloys. Such corrosion, however, usually is of a uniform type, free from isolated pits.

Nominal composition of some aluminum casting alloys suitable for composite engines includes the following:

	Cu	Si	Mg	Zn
319	3.5	6.3	—	—
333	3.8	9.0	—	—
356	—	7.0	0.3	—
380	3.5	9.0	—	—
C612	0.5	—	0.35	6.5

An aluminum-iron engine provides the possibility of galvanic corrosion between the adjacent aluminum and cast-iron components of the cooling system.

For example:

- If excessive coolant flow or abnormal hydraulic conditions are present in the cooling system, erosion or cavitation of the aluminum may occur.
- Improper gaskets may cause crevice corrosion.
- Stuck head studs are sometimes encountered.
- Improper cleaners, unsuitable corrosion inhibitors, and unsafe antifreeze solutions can cause corrosion of the aluminum itself.
- Certain local waters are more corrosive than others to aluminum components.

Resisting galvanic corrosion

The most severe corrosion met with aluminum cylinder heads mounted on cast-iron blocks has been at the coolant ports. There, close proximity to cast iron has resulted in galvanic corrosion. Aluminum alloys 319-F and 333-F, the researches indicate, are most compatible with cast iron because of the low solution potential difference, which is characteristic of them.

Fig. 1 — 250X cross-section of general corrosion in an aluminum-copper-silicon unetched alloy coolant manifold. Note interdendritic nature of corrosion.

There are two ways to alleviate the erosion of the aluminum's protective film, from which accelerated corrosion results when the aluminum has been subjected to the sweeping action of coolant flow:

1. Use a gasket with metering ports at the interface. This can prevent direct impingement of the coolant stream.
2. Use larger ports in the aluminum than in the iron. This, combined with an aluminum casting alloy containing copper (319, 333, or 380) can effectively reduce corrosion at this point.

These recommendations also hold for coolant system components other than cylinder heads that are attached to cast-iron components, such as water pumps, elbows, and thermostat housings.

Preventing erosion

Erosion of aluminum casting alloys takes place when a high-velocity stream of coolant impinges directly on the part. Suspended solids in the stream can scour away the normally protective oxide and

in "composite" engines

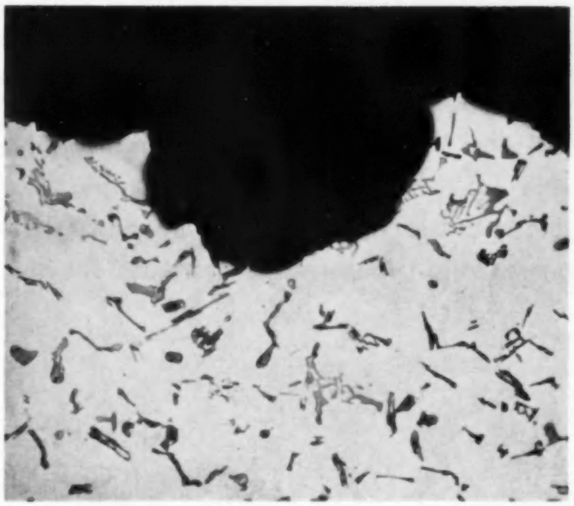

Fig. 2 — 250X cross-section of erosion pit in an aluminum-copper-silicon unetched alloy coolant manifold. Note clean, open nature of pit.

corrosion-product films and cause damage.

This condition is alleviated in a design where the flow is streamlined with a minimum of abrupt turns. Where such changes in flow cannot be eliminated, hard metal inserts may help. Figs. 1 and 2 show the the microstructural difference between general corrosion and erosion in an aluminum-copper-silicon-alloy coolant manifold. Alloy change probably won't make enough difference in resistance to warrant consideration as a correction factor . . . except perhaps with the hypereutectic aluminum-silicon alloys.

Reducing cavitation

The only really effective way to combat cavitation when it occurs is by design . . . to eliminate the source of the vibration that is responsible for the cavitation.

Serious cavitation attack disappeared, for example, in engine components of several diesel engines when the piston clearance was reduced. The cavitation had resulted from the hammer-like collapse of voids in the coolant generated by vibration of the coolant passages. . . . The exciting energy in at least one case was attributed to piston clearance. Reducing the clearance also reduced cavitation attack in some aluminum water-pump housings which had a large impeller clearance.

Use of steel-asbestos or copper as head gaskets keeps away the poultice-type corrosion which may occur when gasket material absorbs water. Intimate contact with these heavy metals has been without serious consequence because of the large anode-to-cathode area ratios involved in the portions wetted by the coolant.

When the gasket material does absorb water, the aluminum in contact with the absorbed water reacts with oxygen dissolved in the water and depletes the oxygen. At an adjacent free surface, the water in the gasket is saturated with oxygen. This variation in oxygen produces a difference in solution potential which can cause corrosion.

Stud clearance needed

Provision of 1/16-in. clearance on the diameter of stud holes in the aluminum cylinder head over the diameter of the studs will eliminate difficulty in removing aluminum cylinder heads from cast-iron blocks. The difficulty will have arisen because of the buildup of galvanic corrosion products between the steel head studs and the aluminum head. Use of cap bolts will help, too.

Coolants and cooling systems

The problem posed to coolant manufacturers by the aluminum-iron engine is to select a corrosion inhibitor compatible with the dissimilar metals. Results of recent work toward that end are encouraging.

In any case, cleaning compounds used in cooling systems should be thoroughly flushed out after each use. Removal must be assured of the cleaning compounds which would be particularly corrosive in a composite engine.

In a composite engine, most inhibitors of iron corrosion actively promote corrosion of an aluminum-iron couple. Introduction of 1% of a naphthenic-base soluble oil, however, has provided a satisfactorily inhibited coolant. Chromates, dichromates, and nitrites should never be used in composite engines. They promote severe galvanic corrosion of aluminum.

Also, use of high conductivity water, particularly high chloride water, should be avoided in a composite engine, because it, too, promotes galvanic corrosion, particularly in the presence of antifreeze solutions.

To Order Paper No. 147B . . .
from which material for this article was drawn, see p. 6.

Jet and turbofan

Based on paper by

S. M. Taylor and C. B. Brame

Pratt and Whitney Aircraft Division, United Aircraft Corp.

Performance differences between a turbofan and a turbojet can be illustrated by comparing the Pratt and Whitney JT3C-7 turbojet engine to their JT3D-1 turbofan engine. Although not exactly comparable, these two engines are about as near to the same state-of-the-art in component efficiency and weight techniques as one usually finds in actual designs.

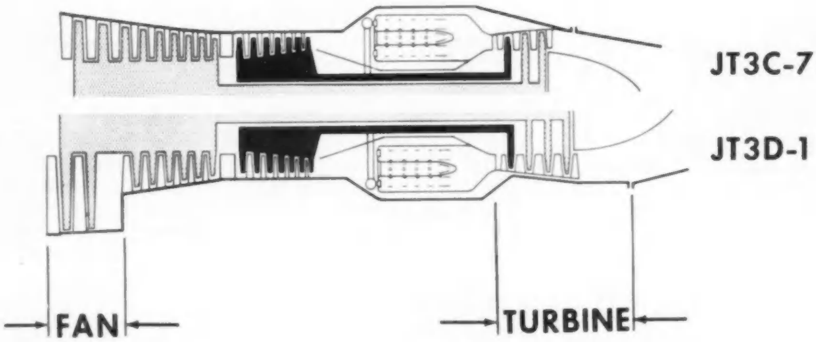

Fig. 1

MECHANICAL ARRANGEMENT OF BOTH ENGINES. JT3D-1 engine was conceived by adding two fan stages to the JT3C-7 in lieu of three compressor stages, and by adding another turbine stage to furnish the added power.

	JT3C-7	JT3D-1
Take-Off Sea Level Static		
Thrust - Lbs	12,000	17,000
TSFC - Lbs/Hr/Lb	.785	.520
Airflow - Lbs/Sec	185	450
By-Pass Ratio	0	1.45
Over-All Pressure Ratio	13	13
Fan Pressure Ratio	0	1.7
Basic Diameter - In.	39	53
Comparable Lengths - In.	122.4	129.1
Weight - Lbs	3,495	4,025
Relative Price	1.0	1.3

Fig. 2

CHARACTERISTICS OF ENGINES COMPARED. Note the increased diameter and length of the turbofan, as well as the large increase in the mass airflow of the engine. Net increase in weight is approximately 530 lb; cost increase is approximately 30%.

performance compared

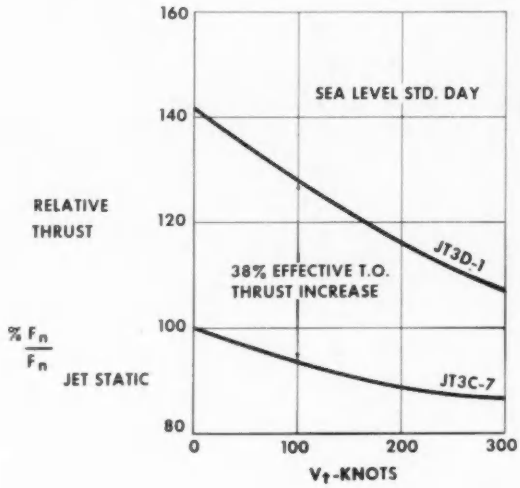

Fig. 3

RELATIVE TAKE-OFF THRUST COMPARISON. Take-off static thrust is increased by 41%. However, effective take-off thrust increase is 38% since the lapse rate of thrust with airspeed of the turbofan is somewhat higher than the lapse rate of the turbojet with airspeed.

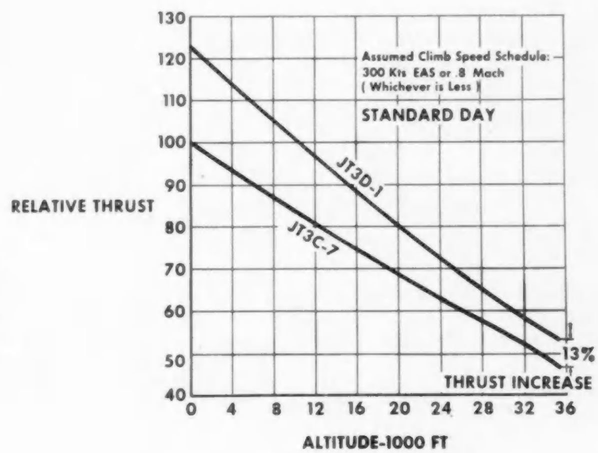

Fig. 4

COMPARISON OF THE CLIMB THRUST AVAILABLE along a typical assumed climb schedule. At low altitudes a 23% thrust improvement is shown, while there is a 13% thrust improvement at high altitudes.

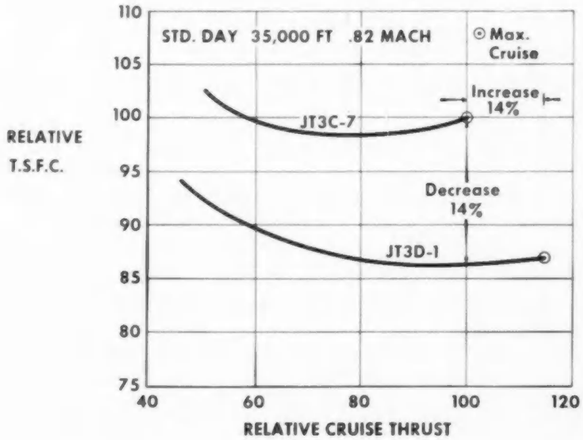

Fig. 5

COMPARISON OF CRUISE FUEL CONSUMPTION at a typical 35,000-ft Mach 0.82 cruise condition. Fuel consumption improvement is about 14%, and increase in maximum cruise thrust capability is about 14%.

To Order Paper No. 172A . . .
from which material for this article was drawn, see p. 6.

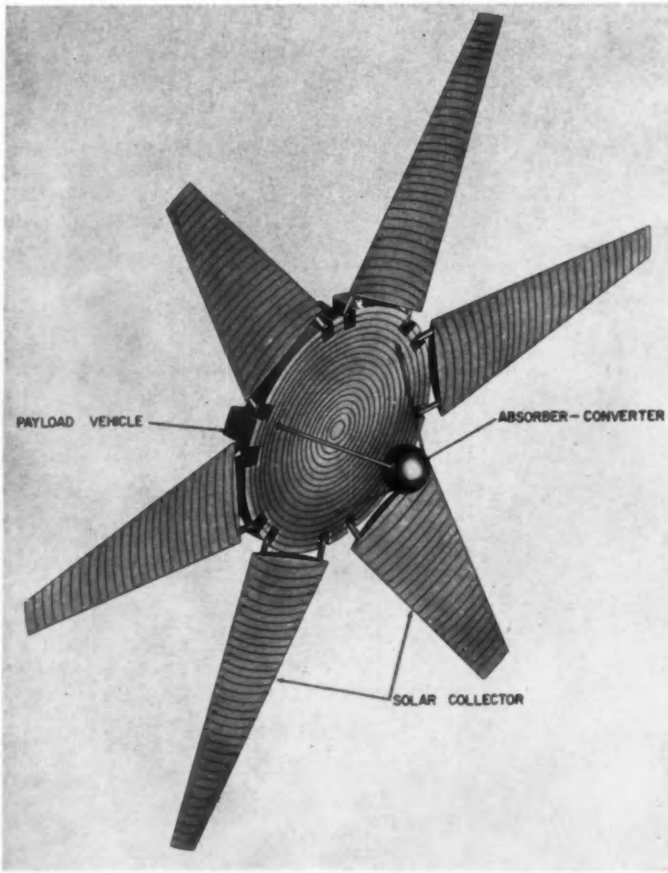

FIG. 1 — Two configurations for solar

Collector designed for solar-thermionic space system

Collection efficiency of 90% or better predicted.

Based on paper by

James G. Leisenring

Missile and Space Vehicle Department, General Electric Co.

SOLAR COLLECTOR DESIGN problems have been solved by a parametric study programmed on a 704 computer. The collector (or concentrator) is one of the basic parts of a solar-thermionic space power system.

Fig. 1 shows two configurations for such a system. The most common type of solar thermionic system would use a paraboloid or cylindrical parabolic concentrator to increase the intensity per unit area to obtain the required operating temperatures.

Collector design

A solar collector system can be obtained by a paraboloid of revolution having its axis directed toward the sun. In this case, all solar energy received by the paraboloid (140 w per sq ft) could be collected at a very small area in the focal plane of the paraboloid — this is the absorber aperture.

thermionic power system.

LEISENRING'S paper describes thermionic converters, their operating characteristics, and their use in power conversion systems.

It presents detailed analysis of a solar-thermionic space power system (500 w).

The solar collector design study is part of this analysis.

However, it is impossible to keep the axis of the paraboloid aimed in the direction of the sun at all times; consequently, it is necessary to determine the loss of collected energy when the axis is at an angle (orientation angle) with direction of the sun. The design can be optimized for given characteristics of the orientation system and the physical characteristics of the materials.

The system of coordinates and relationships is shown in Fig. 2. The diameter ($2H_M$, where H_M is maximum zone height) and the focal length of the paraboloid (f), the position of the absorber aperture, and the orientation angle θ determine the geometry of the system. When the direction of the sun is rotated around the paraboloid axis while the angle θ is maintained constant, the complete system of luminous rays rotates also around the paraboloid axis. Consequently, it is necessary for the absorber aperture to be a circle of radius R having its center on the paraboloid axis.

For purposes of investigation, it is sufficient to consider that the direction of the sun is always in a fixed plane containing the paraboloid axis; this is the meridian plane. The vertex of the paraboloid will be the origin, O, of the system of coordinates, the paraboloid axis being the X axis, the upward tangent to the paraboloid in the meridian plane being the Y axis. The Z axis will complete the right-handed rectangular coordinate system. Since the figure formed by the paraboloid solar collector system and the incident beam having orientation angle θ is symmetrical with respect to the median plane, only the half-space containing the OZ axis and limited by the XOY plane will be considered.

All the incident rays which, after reflection on the paraboloid, pass through the absorber aperture, form a beam of light. The sectional area of this beam perpendicular to the direction of the incident rays is proportional to the amount of energy the collector can receive. Instead of considering this cross section, it is easier to consider the intersection of the incident beam (extended beyond the points of incidence on the paraboloid) with the YOZ plane. If the area in the YOZ plane is A, the cross section area is $A \cos \theta$.

Since existing orientation systems can easily maintain an error angle less than 10 deg, the cosine of which differs from 1 by only 1.5%, the area A will be considered as practically equivalent to the cross section area.

The locus of the points of the paraboloid corresponding to a constant zone height H is a circle in a plane parallel to YOZ and having its center C on the paraboloid axis, at a distance $X = \frac{H^2}{4f}$ from O. There-

Collector designed for solar-thermionic space system

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fore, the projection of this circle on the YOZ plane by a beam of orientation angle θ is also a circle of radius H, having for a center, C', the point of OY at a distance $X \tan \theta$. The diameter MP in the meridian plane is projected onto the diameter $M'P'$ along the Y axis. A point, I, of the circle of center C such that $(CM, CI) = \phi$, is projected into a point I' of the circle of center C' such that $(C'M', C'I') = \phi$ (Fig. 3).

The general method for analysis consists, then, of determining for selected values of zone height H the angles ϕ for which the reflected ray intersects the plane of the absorber aperture at a distance R from the paraboloid axis. The corresponding projections I' on the YOZ plane are then plotted and connected by a continuous line, thus enclosing an area (shaded in Fig. 3B). The ratio of this shaded area to the area of the projected circle corresponding to the maximum zone height (H_M) gives the fraction of energy collected. (This will be called the efficiency of the collector system).

The parameters of interest are: (1) the maximum zone height H_M of the paraboloid, (2) the focal length f of the paraboloid, (3) the radius R of the absorber aperture, (4) the distance X_C from O to the collector plane, and (5) the orientation angle θ. For normalization in a general investigation, the unit length is arbitrary. In the problem of the solar collector, H_M is the natural unit length; hence, only the ratio $\frac{f}{H_M}, \frac{R}{H_M}, \frac{X_C}{H_M}$ have to be considered. However, these ratios are not convenient to plot as in Fig. 3B, which requires consideration of many zone heights smaller than H_M. By taking a unit focal length, many maximum zone heights can be investigated at the same time. Effectively, plots as shown can be made regardless of the maximum reduced height available, $h_M = \frac{H_M}{f}$.

For each h_M, then, the effective area to consider for the energy collected is the portion of shaded area inside the circle corresponding to the zone height h_M, and the fraction of energy collected is the ratio of this limited shaded area to the area enclosed by the circle corresponding to zone height h_M. The normalized quantities, then, are the following:

$h = \frac{H}{f}$ ratio of a zone height to the focal length

$h_M = \frac{H_M}{f}$ ratio of the maximum zone height to the focal length

$r = \frac{R}{f}$ ratio of the radius of the absorber aperture to the focal length

$\varepsilon = 1 - \frac{X_C}{f}$ ratio of the distance from the plane of the absorber aperture to the focal plane to the focal length.

If the location of the absorber aperture is defined by ε, a ray corresponding to the orientation angle θ and intersecting the paraboloid at the point of zone height H and azimuth angle ϕ intersects, after reflection, on the paraboloid the plane of the absorber

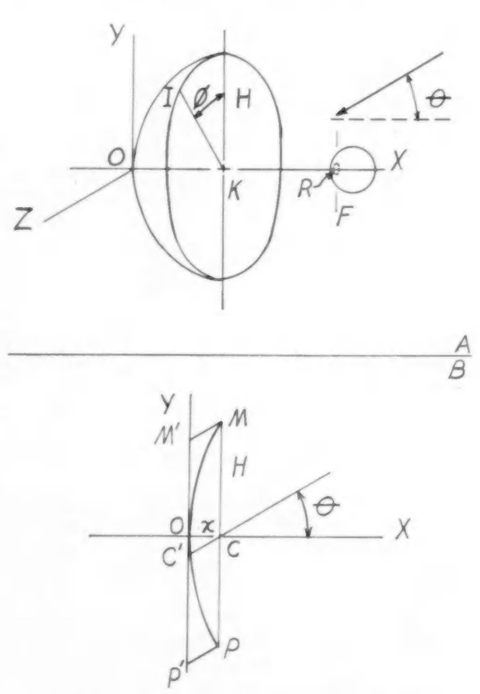

Fig. 2 — Paraboloid optical geometry.

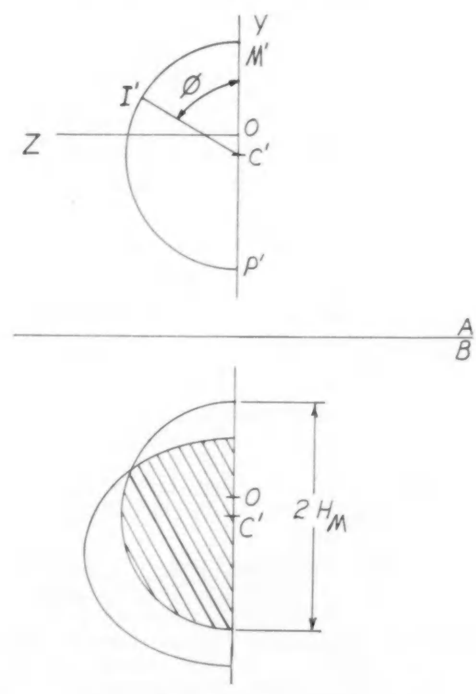

Fig. 3 — Projected rays and area.

aperture at a distance r from the paraboloid axis given by the following equations:

$$r = \frac{(a^2_y + a^2_z)^{1/2}}{1 - \dfrac{h^2}{4} - h \tan\theta \cos\phi}$$

where

$$a_y = -\left(1 + \frac{h^2}{4}\right)\left(1 + \frac{h^2}{4}\cos 2\phi\right)\tan\theta + \varepsilon\left[h\cos\phi + \left(1 - \frac{h^2}{4}\cos 2\phi\right)\tan\theta\right]$$

and

$$a_z = -\left(1 + \frac{h^2}{4}\right)\frac{h^2}{4}\sin 2\phi \tan\theta + \varepsilon \left(h\sin\phi - \frac{h^2}{4}\sin 2\phi\tan\theta\right)$$

These equations have been programmed for the 704 computer. The output of the program gives the following information:

For given θ and ε, the values of r are computed for all combinations of values of h from 0.05 to 2.00 by increments of 0.05 and of ϕ from 0 to 180 deg by increments of 5 deg. For each combination of h and ϕ, r is computed for six selected values of ε. Each line of the 704 output shows:

$h\phi r$ for ε_1, r for ε_2, r for ε_3, r for ε_4, r for ε_5, r for ε_6. The following combinations of θ and ε have been used:

θ	ε_1	ε_2	ε_3	ε_4	ε_5	ε_6
2, 4, 6, 8, 10	0	0.02	0.04	0.06	0.08	0.10
2, 4, 6, 8, 10	0.001	0.002	0.003	0.004	0.005	0.006
1, 3, 5, 7,	0	0.01	0.02	0.03	0.04	0.05

For each value of θ, a transparent master has been prepared, representing the 40 projected circles corresponding to h from 0.05 to 2.00 by increments of 0.05. The center of the projected circle corresponding to h is distant from the origin 0 by $\frac{h^2}{4}\tan\theta$, as in Figs. 2 and 3. On each circle, the points corresponding to values of ϕ from 0 to 180 deg by 5 deg increments have been marked. A length of 200 mm was used to represent the unit focal length for these projected circles. Ozalid copies of these projection masters were made as needed.

To plot the contour of the projected beam on the YOZ plane for given θ, ε and r, the following procedure has been used: For each value of h, determine if there is a value of ϕ for which r has the specified value. A linear interpolation is made to determine the approximate value of ϕ between two successive values of ϕ listed in the 704 output column (corresponding to the specified ε) of the sheet corresponding to the specified θ.

For each value of h, there may be zero, one, or two values of ϕ providing the desired value of r.

The point for $\phi = 0$ is obtained by linear interpolation between the two values of h providing values of r for $\phi = 0$ enclosing the desired value of r. The same procedure applies for the point for $\phi = 180$ deg.

The points of the contour thus determined are connected by a continuous line. Because of the symmetry of the contour with respect to the Y axis,

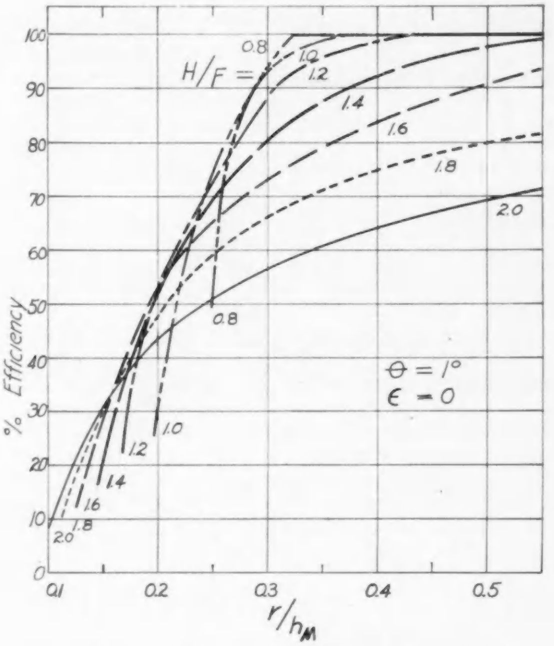

Fig. 4 — Efficiency versus radii ratio and shape factor for one combination of θ and ε.

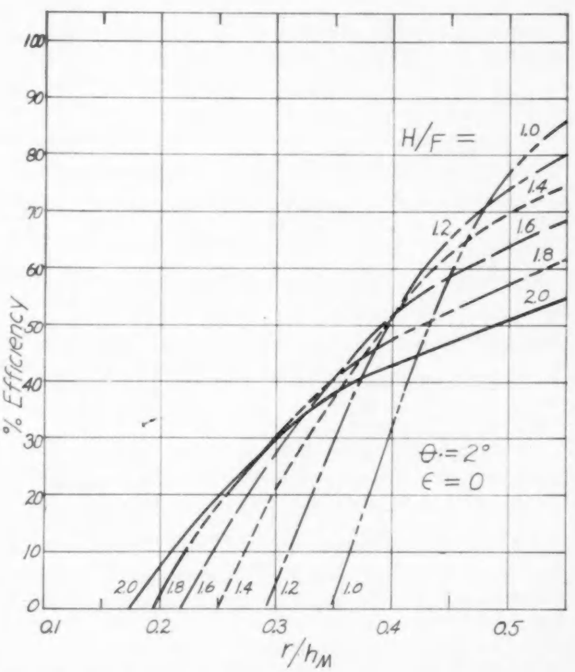

Fig. 5 — Efficiency versus radii ratio and shape factor for a different combination of θ and ε.

Collector designed

for solar-thermionic space system

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the tangents to the contour at the points on the Y axis are perpendicular to the Y axis.

The values of r used mostly have been 0.04 to 0.20 by increments of 0.02; also 0.225, 0.25, 0.30, 0.40 and 0.50.

Most of the plots have been for $\varepsilon = 0$.

The total areas corresponding to various h have been determined with the Amsler planimeter. Since these areas are half circles of known radii, it would have been sufficient to measure the surface of only one of them. However, several circles were measured to determine the accuracy of the measurement when no special precautions were taken. The accuracy was found to be about one percent (the planimeter has an intrinsic accuracy of 0.1%).

The area common to the contour corresponding to a specified r and to the half circles corresponding to a specified h, as in Fig. 3B, was measured with the planimeter and the ratio of the common area to the total area of the half circle computed. This is the efficiency of the system. The operation was repeated for the same r and various h values, and the whole procedure repeated for various h values. Each h is interpreted as an h_M in the discussion below.

Since $\frac{r}{h_M}$, rather than r, is of practical importance, the value of this ratio, $\frac{r}{h_M}$, for each combination of r and h_M used was computed and the corresponding value of the efficiency was then assigned to the set $\left(\theta, \varepsilon, h_M, \frac{r}{h_M}\right)$ of parameters.

Plots were made to produce one graph for a combination of θ and ε. Each graph contains several curves of efficiency versus $\frac{r}{h_M}$ for constant h_M (various values of h were used). See Figs. 4 and 5.

The value of the efficiency for constant $\frac{r}{h_M}$ and various h_M, and for various θ, were read from these graphs. Table 1 summarizes the results for values of $\frac{r}{h_M}$ which are of practical interest for the paraboloid solar collector under consideration.

All results neglect the effect of the shadow of the absorber for two reasons. First, the shape and size of the absorber have not yet been decided. Secondly, for small ratios of $\frac{r}{h_M}$ considered in Table 1, the shadow of the absorber would lower the efficiency by only a few per cent, hence the loss is practically negligible compared to losses which can normally be expected from the coefficient of reflection of the paraboloid and the errors in paraboloid shape resulting from manufacturing tolerances and deformation under various temperature conditions.

It is estimated that the absolute error on the results of Table 1 does not, in general, exceed three per cent, although results are obtained by reading curves determined sometimes only by a few widely separated points. This was considered adequate for rapid investigation. However, if more accurate results are desired for a specific set of $\frac{r}{h}$ and h conditions, it is advisable to determine the contour for a value of $r = h\left(\frac{r}{h}\right)$ and selected values of θ and ε.

This was done in one instance. Since $\frac{r}{h} = 0.07$ and $h = 1.2$ appears to be a promising combination, it was desired to see if an advantage could be obtained using $\varepsilon = 0.02$ instead of 0. The contours were then determined for $r = 0.084$ and the orientation angles 1, 2, 3, 4 deg. Results, listed in Table 1, show that it is not desirable to have the absorber aperture out of the focal plane. The gain in efficiency for higher orientation angles seems very small, while the loss in efficiency for smaller angles seems not negligible. This conclusion was reached in all cases investigated, but additional checks are recommended for the conditions under consideration for the actual design.

It is possible to optimize the design of a paraboloid solar collector when the orientation curve (curve of orientation angle versus time) is known. The curve of efficiency versus orientation angle is plotted for various sets of $\frac{r}{h}$, h from data of Table 1. Then, for

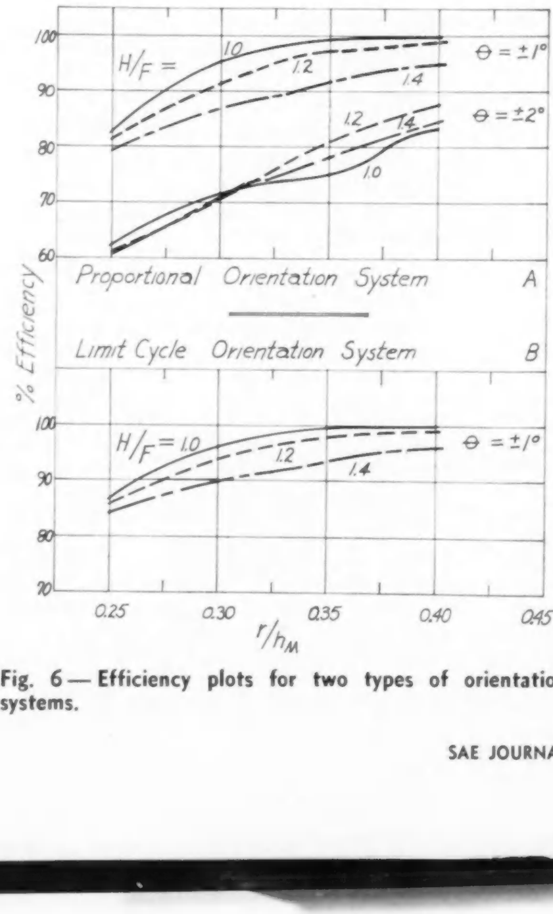

Fig. 6 — Efficiency plots for two types of orientation systems.

each orientation angle of the control curve, the corresponding efficiency is read and the curve of efficiency versus time can be plotted. The average efficiency is determined by area measurement. Various combinations of $\frac{r}{h}$, h can thus be compared, and additional contours determined, if desired, to optimize the design.

Fig. 6 presents efficiency plots for two types of orientation systems. A proportional system, one using inertial wheels, for example, has a time-error angle plot similar to a sine wave. The average efficiency was determined for two orientation angles in terms of the paraboloid geometry parameters (Fig. 6A). The limit-cycle type system, such as one using reaction jets, has a time-error angle plot similar to a saw-tooth wave. Again, the average efficiency was determined (Fig. 6B). From this, it is apparent that the mode of the orientation system affects the collection efficiency of the system. In all cases, the average efficiency will be greater than that determined for a similar constant orientation-angle value.

Throughout this analysis, it was assumed that the collector surface was structurally perfect, that it had 100% reflectivity, and that the absorber body cast no shadow. These factors can now be considered. If the collector area is represented by an h_M equal to the radius of the absorber shadow, this area can readily be subtracted from the effective area previously determined for any orientation angle. The efficiency plots can then be corrected accordingly. As stated previously, this is a very small percentage of the total losses.

The structural accuracy can be related similarly to collection efficiency and use made of the computer analysis. Consider a small increment of the collector surface, dA. The angular deviation of the normal drawn at its center to the normal drawn to the corresponding ideally positioned area dA′ can be considered in the same manner as the orientation angle. Since this angle can exist in any plane through the ideal normal for each dA considered, the rms value of all angular deviations taken over the entire collector surface should be used. This is necessary because each angular deviation of a dA can add to or subtract from the orientation angle at any given instant of time. Thus, the physical tolerances of the collector surface can be converted to angular tolerances and the effective loss in efficiency determined.

After the shadow factor and the structural accuracy factor have been included in the collection efficiency, it can be multiplied directly by the reflectivity of the collector material. A study of the available materials for collector fabrication indicates that a reflectivity close to 0.95 can be attained. Tests in a space environment have not been conducted to verify this value. It has been concluded that an effective collection efficiency of 90% or better can be realized in an actual system by proper design optimization.

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from which material for this article was drawn, see p. 6.

Table 1 — Efficiency (%) for Various Combinations of r/h_M, h_M, and θ. No Shadow; $\varepsilon = 0$ or As Marked.

		θ, deg									
r/h_M	h_M	0	1	2	3	4	5	6	7	8	9
	1.0	100	100	69.5	0	0	0	0	0	0	0
	1.2	100	100	74	22	0	0	0	0	0	0
.05	1.4	100	98	69.5	33	0	0	0	0	0	0
	1.6	100	91	64	38	12	0	0	0	0	0
	1.8	100	80	57	37	17.5	2.5	0	0	0	0
	2.0	100	69	51	35.5	21	8	0	0	0	0
	1.0	100	100	91	31	0	0	0	0	0	0
	1.2	100	100	86	49	7.5	0	0	0	0	0
.06	1.4	100	100	78	54	23.5	0	0	0	0	0
	1.6	100	95.5	72	51.5	27.5	8.5	0	0	0	0
	1.8	100	85	65	48	29	14	2	0	0	0
	2.0	100	72	56	43	30	18	7.5	0	0	0
	1.0	100	100	98	62	0	0	0	0	0	0
	1.2	100	100	95	68.5	33.5	0	0	0	0	0
	1.2	100	100	89	69	33		($\varepsilon = 0.02$)			
.07	1.4	100	100	87	66	41	14	0	0	0	0
	1.6	100	98	79.5	61	41	21	5.5	0	0	0
	1.8	100	88	69.5	55	39	25	12	0	0	0
	2.0	100	75	61	49	38	27	17	0	0	0
	1.0	100	100	100	81	30.5	0	0	0	0	0
	1.2	100	100	99.5	81	51	15.5	0	0	0	0
.08	1.4	100	100	92.5	74	53	28.5	7	0	0	0
	1.6	100	100	84	68	51	34	17.5	0	0	0
	1.8	100	90	74	59.5	47	34.5	22	6	1.5	0
	2.0	100	77	64	52	43	34	24	12	7	0

All-Weather System Lands Aircraft Automatically and Reliably

Present investment in ILS equipment throughout the North American and European continents makes it unlikely that a major new system will be substituted in the next decade. Thus, the All-Weather Landing System described here is meant to meet the needs of current military and impending commercial requirements.

Based on paper by

E. W. Velander

Autonetics Division, North American Aviation, Inc.

THE All-Weather Landing Set is a complete ILS-type landing system, including initial and final approach, touchdown, and runway rollout. It provides the touchdown capability required for a manual landing or, when coupled to an automatic flight control system (AFCS), provides fully automatic approach and landing under zero ceiling and visibility conditions. It consists of:

- Sensory equipment.
- Computational equipment — flare computer.
- Output elements.
- Auxiliary equipment.

Fig. 1 is a block diagram of the All-Weather Landing Set. It shows both lateral and longitudinal modes of control.

Sensory equipment

The sensory equipment includes:

1. ILS guidance.
2. Airborne localizer and glide-slope receiver.
3. Radar altimeter.
4. Instantaneous rate of descent (IRODS).
5. Basic sensory elements of the flight control system, for example, pitch, roll, and yaw rate; pitch and roll attitude; and pilot control stick position.

The sensory equipment provides spatial guidance and airborne sensory instrumentation for the landing system.

Spatial Guidance — Because of the present problems of initial investment and installation, the automatic landing systems of the immediate future will undoubtedly use ILS equipment of the types already developed. Recent improvements in narrow localizer and glide-slope beams have opened the door to satisfactory capabilities in ILS equipment of the type similar to the MRN 7 and 8 transmitting and receiving sets. The airborne receiving equipment could be of the ARN 31 localizer and glide-slope receiver configuration. The addition of a middle marker beacon, to provide an indication of when the aircraft is 100 ft above the level of the runway, would serve as a backup for flare initiation and a checkpoint for the pilot, but is not considered mandatory.

Airborne Sensory Instrumentation — The primary aspects to be considered in a discussion of airborne sensory instrumentation are the role of the radar altimeter and the IRODS element.

a. Radar altimeter: The radar altimeter is used to establish the point of flare initiate and to provide a continuous signal proportional to the height of the aircraft above the level of the runway. Basic requirements are for an altitude accuracy of 2 ft $\pm$ 2% for 0–1000 ft, and an output signal linear with the height above the terrain. The radar altimeter must be able to provide a reasonably smooth derivative of altitude signal and have a relatively short time constant. Ideally, step errors should be avoided, but must, in any case, be held to an extreme minimum, and the output must exhibit a reference altitude stability of 1 ft or better under landing conditions.

An investigation of existing and proposed altimeter developments showed a modified version of the Emerson APN 100 to be the most acceptable radar altimeter. The Emerson Radio and Phonograph Corp. has fabricated a radar altimeter that meets the accuracy requirements, and avoids the step error, usually found in fm-cw radar altimeters.

The fm-cw radar altimeters measure heights by comparing the frequency of returned transmitted

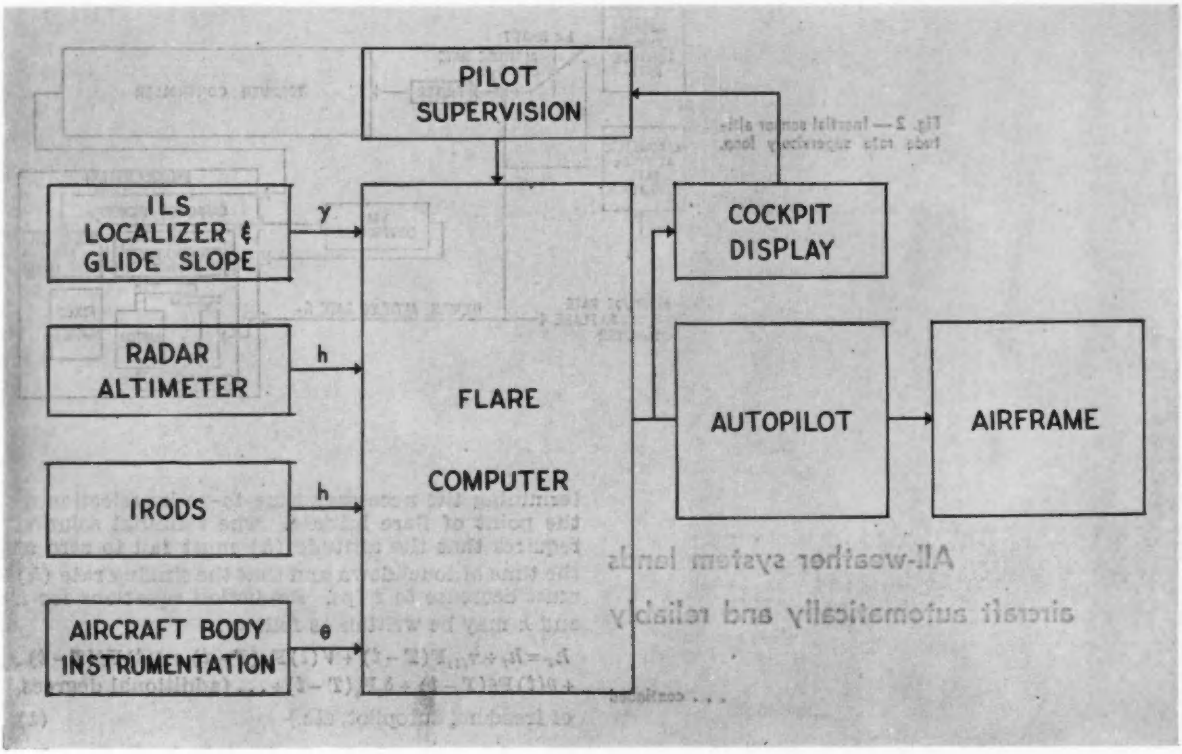

Fig. 1 — Block diagram of All-Weather Landing Set, showing both lateral and longitudinal modes of control.

signals with the instantaneous transmitter frequency. The differential frequency is proportional to the two-way propagation time, and, therefore, to altitude. The Emerson APN 100 derives height by maintaining a constant modulation index of the differential frequency spectrum (ratio of frequency deviation to the frequency of the modulating wave). This index is measured at the mixer output and kept constant by a servo loop that adjusts the frequency deviation of the Klystron transmitter tube. The output of the servo loop contributes a signal linear with altitude and an altitude rate signal and, because the servo feedback is continuous, the step error is eliminated.

b. IRODS: The IRODS element measures altitude rate by means of a velocity meter.

(1) Altitude rate: The altitude rate as obtained by differentiation of radar altitude, though a required signal, presents difficulties in the form of noise, time lags, terrain irregularities, and signal path geometry, and altimeter operating nonlinearities when used in a landing system. Because the bulk of these problems is centered about the high-frequency portion of the altitude signal, it is feasible to adopt inertial sensing devices with superior high-frequency characteristics and, in this way, supply the highly accurate sinking rate information required in the flare computer.

(2) Velocity meter: The heart of the IRODS element is a velocity meter that is capable of converting acceleration into velocity information. Basically, the velocity meter is an acceleration sensing mass or pendulum, supported on low-friction bearings, with a rotating magnet oriented to apply a drag torque on a pendulous element and capable of holding the pendulum at null. If the instrument is accelerated along its sensing axis, a torque must be applied by rotating magnets with an angular velocity proportional to the applied torque. As a consequence of this arrangement, the angular velocity of the drag magnet is proportional to the input acceleration, and the magnet shaft angle is proportional to the output velocity. The velocity meter controller senses the pendulum angle and supplies power to the magnet drive motor in a proportion that will hold the pendulum at null.

For the velocity meter to integrate from a given condition, an initial rate-of-descent signal is necessary. During the approach phase, a barometric rate-of-descent sensor supplies this information; whereas, during the flare phase, the radar altimeter rate is used. The velocity meter is kept stable and in a fixed plane by a stable platform aligned to the flight control system vertical gyro. Fig. 2 is a block diagram of the velocity meter and the IRODS supervisory loop.

Additional sensory information is obtained from the flight control system rate gyros and a pilot control stick position transducer to supply the necessary body rate information for stabilization.

Flare computer

The terminal control flare computer utilizes the information provided by the airborne sensing ele-

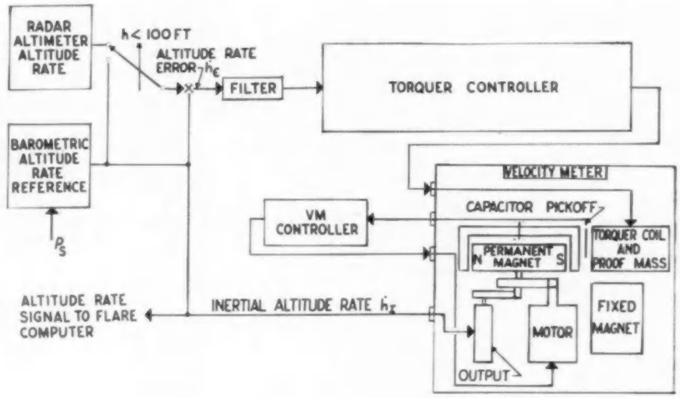

Fig. 2 — Inertial sensor altitude rate supervisory loop.

All-weather system lands aircraft automatically and reliably

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ments and the ground spatial information to compute the solution to the prediction equations necessary to achieve a landing under the specified terminal conditions.

Many of the existing methods used for the design of landing control systems, the effectiveness of which depend on satisfying terminal conditions, utilize ordinary servomechanism techniques that attempt to zero an error signal at all times. This restriction of minimizing an error weighted equally for all times may reduce the performance achievable with a specific dynamic element at a particular time.

Terminal controllers are characterized by the requirement that the controlled system response (output) must equal the forcing function (input) command at a particular time designated as the terminal time, with the response at other times being arbitrary.

The differential equations that describe the dynamic behavior of the controlled system can be solved for any future instant in time, based on the knowledge of the equations of motion of the system and the known values of the parameter at that instant of time. This fundamental feature of the terminal controller provides the required control action for the time solution of differential equations based on initial conditions taken at a given time.

The two dominant parameters in the time solution of landing control equations for aircraft are h (height above the level of the runway) and $\dot{h}$ (the sinking rate). A third parameter is the time remaining to touchdown $(t-T)$. If an accurate "range" signal is available, this can be used to monitor the time-to-go parameter for minimum dispersion on the runway. Altitude accuracy during flare is necessary because this provides the basis for determining the necessary time-to-go by selection of the point of flare initiate. The terminal solution requires that the altitude (h) must fall to zero at the time of touchdown and that the sinking rate $(\dot{h})$ must decrease to 2 fps. Prediction equations for h and $\dot{h}$ may be written as follows:

$$h_T = h_t + \gamma_{(t)}\mathbf{F}(T-t) + V(t)\mathbf{F}_V(T-t) + \theta(t)\mathbf{F}\theta(T-t) + \dot{\theta}(t)\mathbf{F}\dot{\theta}(T-t) + \delta_s\mathbf{F}_s(T-t) + \ldots \text{ (additional degrees of freedom, autopilot, etc.)} \quad (1)$$

$$\dot{h}_{(T)} = \dot{h}_{(t)} + \gamma_{(t)}\mathbf{G}_\gamma(T-t) + V(t)\mathbf{G}(T-t) + \theta(t)\mathbf{G}\theta(T-t) + \dot{\theta}(t)\mathbf{G}\dot{\theta}(T-t) + \delta_s\mathbf{G}\delta_s(T-t) + \ \ldots. \quad (2)$$

where:

h = Altitude
$\dot{h}$ = Altitude rate (sinking rate)
F, G = Weighting functions
γ = Flight path angle
V = Airspeed of aircraft
θ = Pitch attitude
$\dot{\theta}$ = Pitch rate
δ_s = Control surface deflection
T = Touchdown time
t = Present time

The weighting functions F and G are determined empirically for each type of aircraft, and include such parameters as average trim, aircraft autopilot response, and ground effects.

a. Time solution of prediction equations: The following is a brief explanation of the time solution of prediction equations based on the equations of motion of a mass undergoing constant acceleration.

(1) Altitude rate prediction: The altitude rate prediction is based on the equation of motion:

$$V = at + V_o \quad (3)$$

and the predicted altitude rate is represented by:

$$\dot{h}_{(t=T)} = \ddot{h}(T-t) + \dot{h} \quad (4)$$

By referring to Fig. 3, it may be noted that the controller $\dot{h}_c$ signal at any instant of time approximates an acceleration signal $(\ddot{h})$ because of the time response of the aircraft to the altitude rate command $(\dot{h}_c)$.

At any time during the flare, the $\dot{h}$ predictor samples the output of the controller, compares this

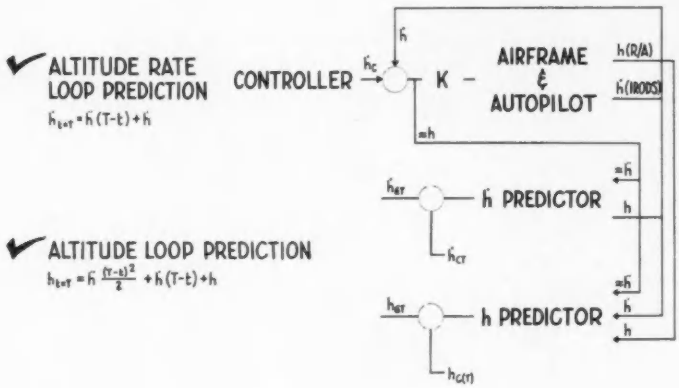

Fig. 3 — Altitude and altitude rate prediction.

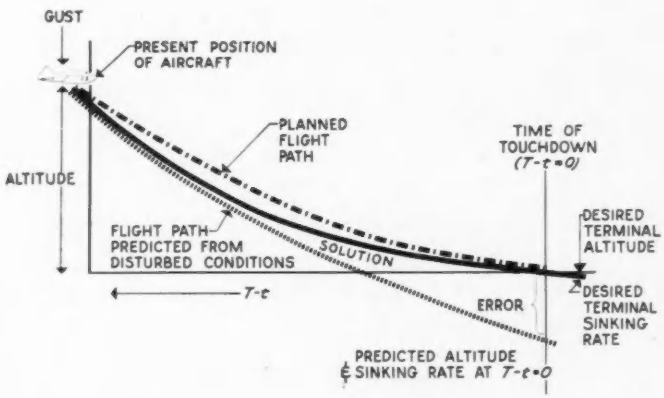

Fig. 4 — Two-condition terminal controller.

with the sinking rate as measured by the IRODS, and generates a predicted sinking rate ($\dot{h}_{pT}$) at touchdown based on present conditions. This $\dot{h}_{pT}$ signal is summed with the commanded sinking rate at touchdown ($\dot{h}_{cT}$) to produce an $\dot{h}$ error command ($\dot{h}_{\epsilon T}$).

(2) Altitude prediction: The altitude prediction is based on the equation of motion:

$$S = \frac{at^2}{2} + V_0 t + S_0 \qquad (5)$$

and the altitude prediction is based on the equation:

$$h = \ddot{h}\frac{(T-t)^2}{2} + \dot{h}(T-t) + h \qquad (6)$$

where:

t = Present time

$T - t$ = Time remaining to touchdown

In a similar manner the h predictor samples the output of the controller, comparing this with the present altitude as measured by the radar altimeter and the product of the sinking rate ($\dot{h}$) and time-to-go to touchdown ($T - t$) to generate a predicted altitude (h_{pT}). The h_{pT} signal is summed with the commanded altitude at touchdown (h_{cT}) to produce an h error signal ($h_{\epsilon T}$).

(3) Corrective action: The $h_{\epsilon T}$ and $\dot{h}_{\epsilon T}$ signals are fed to the h and $\dot{h}$ correctors to modify the $\dot{h}_c$ command signal in a manner that will drive each of these error signals to zero. A further modification of the h_{pT} prediction is necessary to include the effects of the correction commanded by the $\dot{h}$ prediction loop (Fig. 4).

b. Typical flare: A typical flare using the terminal controller may be divided into three parts: (1) the initial phase immediately after flare initiate, (2) the steady flare phase, and (3) the touchdown phase.

If there are no disturbances, the predictor functions as follows:

1. At a particular instant of time shortly after flare initiate, the predictor samples the output of the controller. If the sampled control command remains constant until touchdown, the aircraft may land high (Fig. 5). The correction sent to the controller drives the $h_{\epsilon T}$ to zero and results in a modified flare (Fig. 6).

2. A sample taken at another instant results in a similar action. As the aircraft approaches touchdown, the gain is revised, resulting in the attainment of the present terminal conditions. This type of control action is continuously being applied throughout the flare. The path described is similar to an exponential flare, during which the time constant is continuously being varied in a way that will satisfy the terminal conditions.

3. If during flare a wind condition perturbates the aircraft from the controlled path (Fig. 7), the h and $\dot{h}$ predictors command a correction to satisfy the terminal conditions, rather than a return to the

All-weather system lands aircraft automatically and reliably

. . . continued

previous flare path. Should the pilot choose to effect a correction by pulling back on the control stick, the input to the flare computer will stretch the time-to-go in direct proportion to the force and time the control stick is held. Upon release, the predictors will command a new flare path based on the extended time (Fig. 8). If a wind arises or other perturbation occurs, as time runs out, the aircraft is commanded down at the rate of 2 fps by a fixed bias.

c. Terminal controller test results: The results of an experimental terminal controller in an F-100F aircraft have proved the theory of terminal control. For example, the predicted altitude error h_p remains approximately equal to zero throughout the flare. The altitude rate command $\dot{h}_c$ and altitude rate error $\dot{h}_p$ are high during the early portion of the flare, but immediately correct to satisfy the terminal conditions.

d. Hardware: The electrical and electronic hardware developed for landing system control are of an advanced design. Transistor circuits are used throughout. Reliability is enhanced by etched circuit board interconnection. Amplifiers are of the module plug-in type and are readily accessible for replacement or repair.

Output elements

One of the major problems to be faced in the application of automatic landing systems to routine operations is that of pilot confidence and acceptance. The pilot must be able to monitor the forthcoming control action continuously, as well as to evaluate the performance. Much has been accomplished by military agencies and industrial concerns in providing adequate flight direction and situation instruments.

Cockpit Display — Fig. 9 portrays the layout of instrument display being used in a TF-102 test aircraft. The attitude director indicator (ADI) and the horizontal situation indicator (HSI) occupy the central portion of the instrument panel. The altitude and sinking rate meter is positioned to the right of the ADI, while the speed brake position indicator and mode lights are to the left of the HSI. The control panel for the landing system and the AFCS are immediately below the instrument panel, in a position allowing ready access to the control panel by the left hand of the pilot.

The normal compass heading course command and heading commands are placed on the HSI. The output of the approach coupler during the approach, flare, and runway rollout for steering information is placed on the bank director needle of

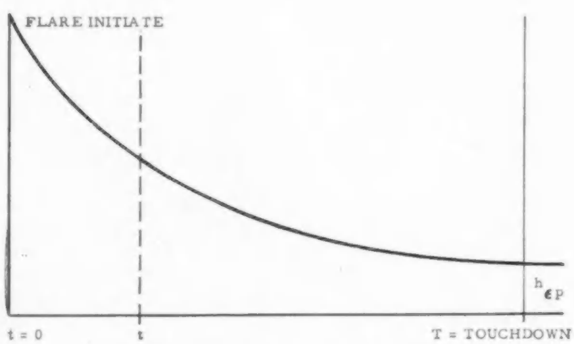

Fig. 5 — Aircraft landing high prediction.

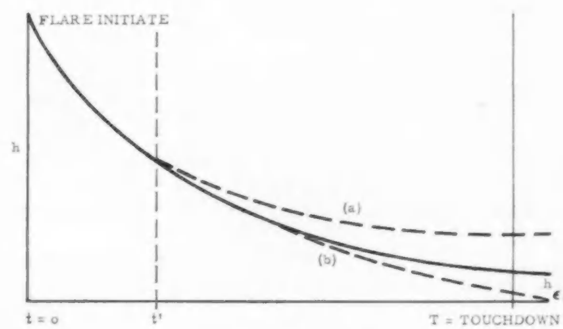

Fig. 6 — Modified flare.

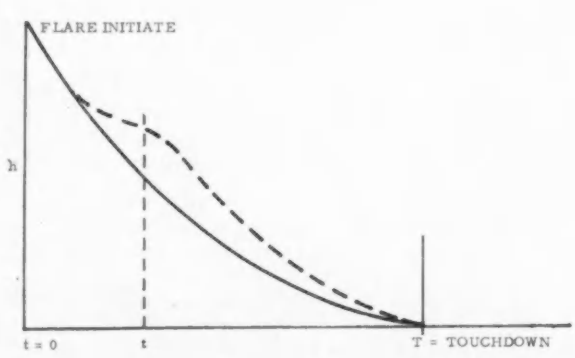

Fig. 7 — Gust perturbation and correction.

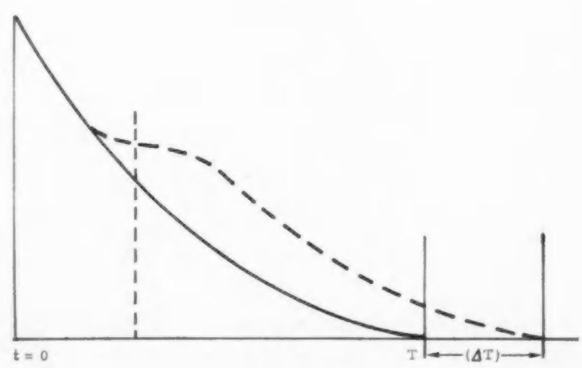

Fig. 8 — Pilot override.

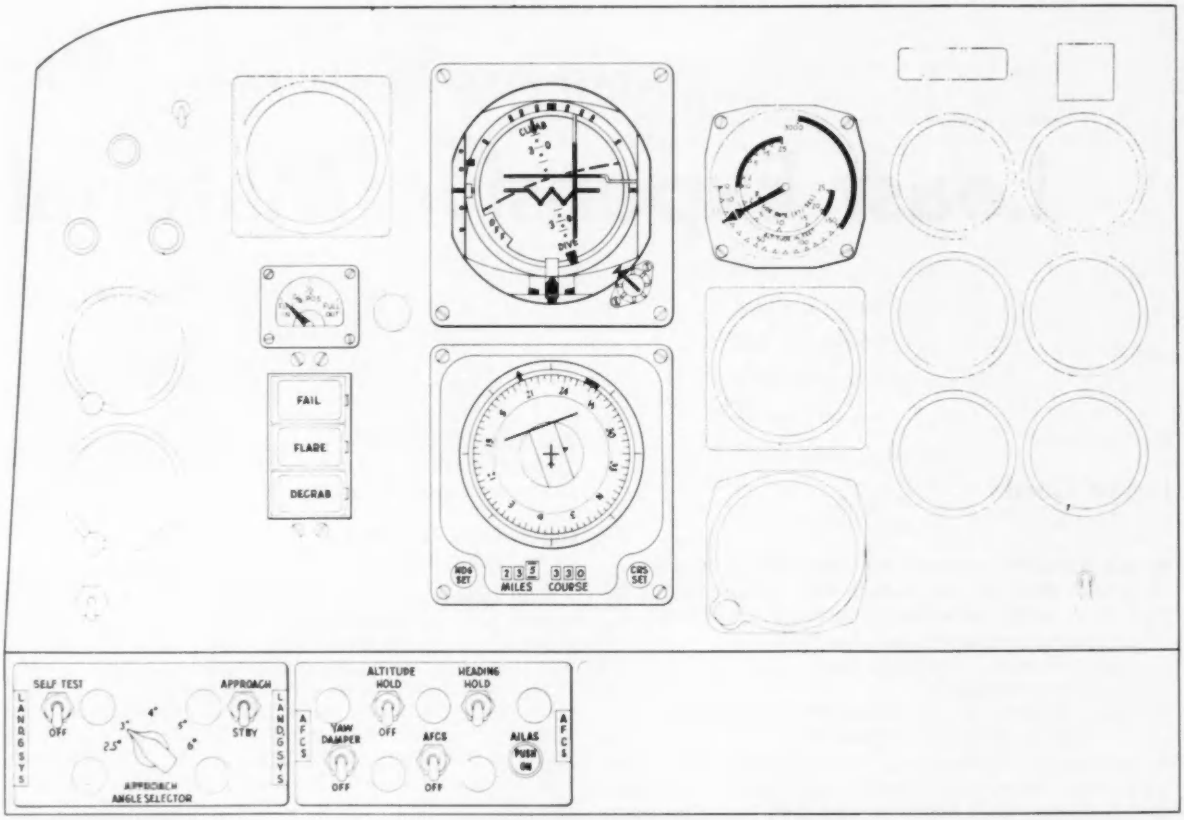

Fig. 9 — Layout of instrument display being used on TF-102 test aircraft. Attitude director indicator (ADI) and horizontal situation indicator (HSI) occupy central portion of panel. Altitude and sinking rate meter is positioned to right of ADI. Speed brake position indicator and mode lights are to left of HSI. Control panel for landing system and AFCS are immediately below instrument panel, in a position allowing ready access to control panel by left hand of pilot.

the ADI. During the approach, hold altitude information is fed to the pitch director needle until glide-slope entry, at which time it is switched to augmented glide-slope error. At flare initiate, the pitch director needle is switched to the output of the flare computer. Raw glide-slope error is presented on the glide-slope displacement point (h_g) during the approach phase.

AFCS Coupler — To accomplish an automatic landing requires an AFCS capable of stabilizing the aircraft during flare and responding in a reasonable manner to input commands. The basic control loop is the altitude rate.

As the aircraft closes in on the runway, the gains of the localizer and glide-slope error beams gradually increase. Some means must be provided to schedule the gains. Generally, barometric altitude offers the best solution, at least down to an altitude of 100 ft above the level of the runway.

Auxiliary equipment

Auxiliary equipment provides for speed control and control stick steering.

Speed Control — Speed brake and throttle control are used to maintain a preset indicated airspeed during the glide-slope phase in both manual and automatic modes of operation. At flare initiate, the speed brakes are driven slowly to the full-open position and the throttle is slowly retarded as a new touchdown ILS reference is selected. At touchdown, the throttle is retarded to the idle position and full-open speed brake is commanded. Deployment of the drag chute must be accomplished by the pilot.

The pilot can, at any time, override the automatic throttle and speed brake controls. The speed brakes operate proportionately as a function of instrument airspeed error from the nominal values.

Control Stick Steering — The addition of control stick steering to the flight control system provides the pilot with the means of adjusting his glide-slope and flare path control, should the situation so require. Also, the pilot is furnished with a method of position control, should an emergency develop in the flare system. Consequently, the pilot can initiate corrective action without the transient of disengagement when close to the ground. Although not available in all aircraft, control stick steering is becoming an accepted method of pilot input to the flight control systems being planned for future use.

To Order Paper No. 171C . . .
from which material for this article was drawn, see p. 6.

CASE HISTORIES point way to choosing the

Least Expensive Material

for any required part

Based on paper by

Joseph Gurski
Ford Motor Co.

THE LEAST EXPENSIVE MATERIAL for a required part can be chosen only after consideration of all potential areas for savings, including:

1. Reduction of metal cost
2. Reduction of process cost
3. Standardization
4. Stabilization of engineering drawings
5. Use of standard tolerances.

Automotive experience is ripe in examples where consideration of these areas has realized savings; and in cases where decisions resulted in higher costs because such considerations were neglected or slighted.

Piston pin costs drop with switches in material

Selection of the material for the automotive piston pin shown in Fig. 1 is a case in point. Actually, several material changes were made — some cost reduction resulting from each change.

Originally the pin was made from tubing. The first cost reduction came when it was decided to use a bar steel — and drill the hole. The resulting saving was $0.08 per 8-cyl engine. A greater weight of raw material was used, but its cost per pound was substantially lower.

Because of the critical nature of the part and the proximity of raw material size to finished pin diameter, a costly "piston pin quality" was specified. Review of the part processing suggested another course of action. The ordering size of the bar was increased by 0.010 in., the "piston pin quality" requirements removed, and less costly magnetic testing inspection specified. The increased size permitted more stock removal so that small surface imperfections not revealed by inspection were machined off. Again, a small increase in the raw material weight was more than offset by the lower cost per pound and $0.04 per engine was saved.

Later, the development of cold forming techniques resulted in saving the metal that would normally be machined off and thrown away as chips while still paying the lower cost for metal in the form of bars. This change in processing saved an additional $0.10 per engine. It also resulted in substantial reduction of floor space requirements and in the reduction of initial equipment outlays.

Quality holds, costs drop on rear axle driving gear

The rear axle driving gear (Fig. 2) is relatively heavy and is made from comparatively expensive alloy steel. Originally, SAE 4620 steel containing about 2% nickel-molybdenum alloy was used. Later it was found that SAE 8620 with about 1.1% nickel-molybdenum-chromium alloy was adequate and $0.15 per vehicle was saved. Further examination resulted in the use of SAE 4028, with 0.25% molybdenum, in many cars for an additional saving of $0.07 per vehicle. Therefore, a total saving of $0.22 per vehicle was achieved with no reduction in quality.

Rear axle shaft properties improve, costs fall

The rear axle shaft (Fig. 3) requires 14.6 lb of steel to make a forging and two forgings are required per vehicle. By changing material from SAE 1330 steel to SAE 1038 steel, a saving of nearly $0.50 per automobile was realized. Further, the utilization of induction-hardening techniques in place of through-hardening resulted in improved physical properties. When increasing horsepower and increasing torque requirements would have necessitated going to a larger section for the alloy shaft, it was possible to retain the smaller shaft. Here is an unusual case where increased requirements have been met with a cost saving.

Material, process changes mean savings for bearing race

The universal joint bearing race (Fig. 4) was made from SAE 1018 steel on conomatics, then copper plated all over. To obtain selective hardening, plating was machined from ID wall by plunge grinding and from ID face by a turning operation. The part was then carburized, quenched, and finish ground on the ID.

The steel was revised to one of 0.50% carbon, 1.50% manganese, and 0.28% sulfur. The processing was changed from carburizing to induction hardening on a station of the conomatic. A saving of $0.035 per piece was realized. Since eight pieces

PRACTICAL EXAMPLES of how proper material selection methods keep costs down are detailed in the case histories which comprise this article.

THE FACTS are given about selection methods used and the results obtained in the case of:

- Automotive piston pin
- Rear axle driving gear
- Rear axle shaft
- Universal joint bearing race
- Radiator tubes
- Water pump pulley hub

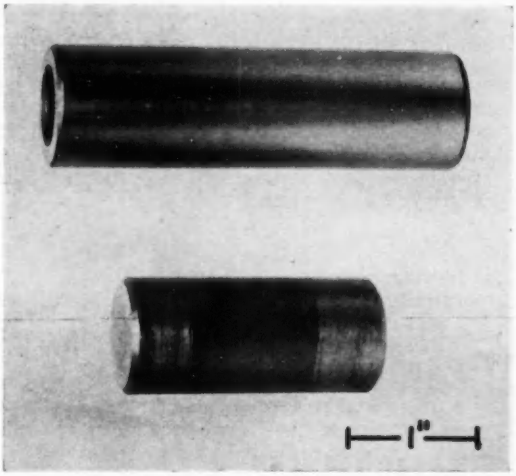

Fig. 1 — Finished piston pin (top) and slug for cold forming (bottom).

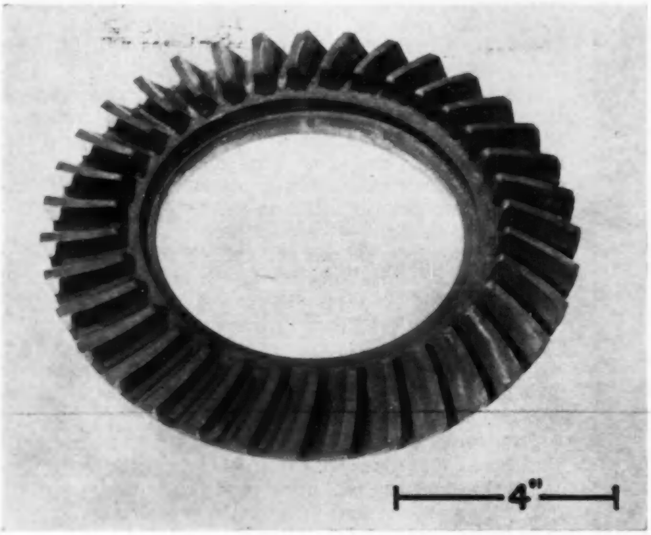

Fig. 2 — Rear axle driving gear.

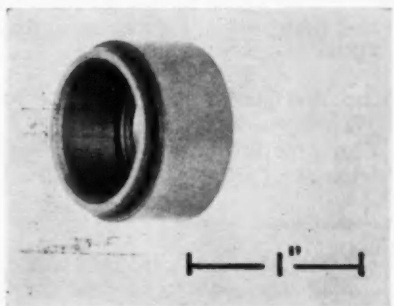

Fig. 4 — Universal joint bearing race.

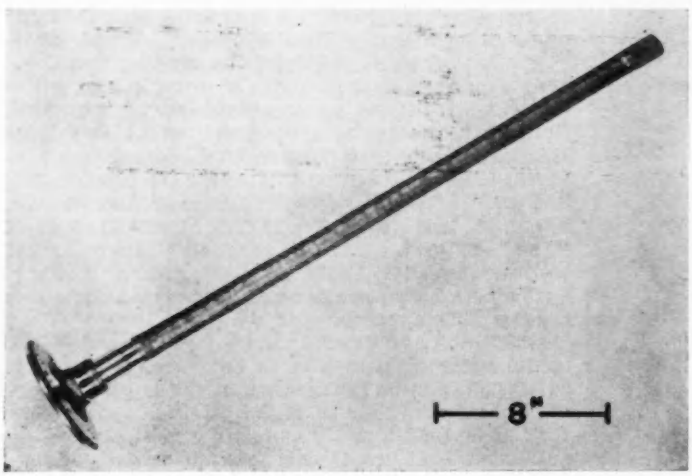

Fig. 3 — Rear axle shaft.

Least Expensive Material

. . . continued

were used per car, the total savings amounted to $0.28 per car.

Savings were effected by eliminating the following:

1. Copper plate.
2. Plunge grinding operations on ID wall after plating.
3. Turning operation on ID face after plating.
4. Carburizing operation (induction heater is on a station of the conomatic).
5. Necessity for float prior to and after carburizing operation, saving floor space.
6. Handling between operations.
7. Grinding ID after heat treat, as distortion is held to a minimum.

Smooth contours over welded joints of body sheet metal have been traditionally achieved by using a filler metal or body solder. Although the amount of body solder required may vary somewhat from year to year, 6 lb per vehicle is not an unusual amount. While it was impractical to eliminate body solder, cost reductions were effected by reducing the tin content of the solder. Reducing tin content from 30% to 2.6% resulted in about $0.21 per pound savings, even after allowing for the higher specific gravity of lead. It is surprising in how many cases this cost factor is disregarded. Many times the advantage of being able to apply higher tin solders more easily is used as justification for a substantial increase in metal costs.

Selection of solders for radiators is also important since a radiator requires about 3 lb of solder. With the price of 40%-tin solder being $0.10 per pound more than the price of 30%-tin solder, the choice of which solder to use is important since it involves a difference of $0.30 per assembly. Obviously, processing costs must be considered. However, in many cases they are not significant and most of the metal savings can be realized.

Scrap reduction saves $ on radiator tubes

Radiator tubes were formerly made from rolled-to-temper cartridge brass approximately quarter-hard. Investigation of a brass produced by annealing to temper, which had a much smaller grain size and gave higher tensile strengths and much more ductility, proved that "in-process" scrap could be reduced (Fig. 5). In addition, a finished product much more resistant to fatigue was produced. At one plant alone a scrap reduction valued at $1200 per week was realized through an adoption of this material with a resultant improved product.

THE MATERIAL IN THIS ARTICLE is drawn from a paper by Joseph Gurski, manager, Chemical and Metallurgical Laboratory Services, Ford Motor Co.

The paper was presented before Federation Internationale des Societes d'Ingenieurs des Techniques de l'Automobile (FISITA) at the Hague.

Gurski was invited to present the paper by FISITA at the suggestion of the SAE Engineering Materials Activity Committee.

Stabilized drawings permit material substitutions, bring savings

Revisions to engineering drawings are accepted as necessary operations, as indeed they are. However, to the extent they can be reduced while maintaining accurate and proper specifications, a saving is realized. The use of the techniques mentioned in this article resulted in reducing engineering changes occasioned by metallurgical reasons by 80% over a period of years. When each change is estimated to cost from $2000–5000 in a large company, it is easy to envision opportunities for reducing costs. Naturally, savings in smaller organizations would be proportionally less but certainly still significant. In addition, a review of these techniques will disclose many other even more important benefits.

A basic factor in the stabilization of drawings is the realization that it is not practical to tell a manufacturer what is desired in a finished part and tell him how to do the job. This divides responsibility and the best procedure is to specify the desired attributes and permit latitude in materials and processing.

A number of devices for stabilizing engineering drawings are used, one of which is Ford Standard M2K2 Carbon Steel — Permissible Substitutions. Following are significant excerpts from the text of the standard: The scope, paragraph 1.1 states "This standard is intended to permit the widest possible latitude for manufacturing consistent with engineering drawing end requirements."

The requirements — paragraph 2.1 states "This standard recognizes that many steels will give physicals that are equal to or better than those specified. It also recognizes that free cutting steels can be used instead of conventional carbon steels."

Paragraph 2.6 cautions "Listing steels as options shall not be construed as a guarantee that they can all be fitted into a particular process. Proper processing is the responsibility of the supplier."

An engineering drawing of a water pump pulley hub (Fig. 6) indicates how this standard is applied. Note that the material is specified as SAE 1020 (M2K2E) steel. Referring to M2K2, paragraph 3, — Permissible Substitution Chart (Fig. 7), observe that SAE 1020 (M2K2E) permits the use of AISI-C-1023, SAE 1025, 1027, 1030, 1033, 1035 or M2K2F through K steels. In groups M2K2F through K there are 29 additional grades. With all these options, it should not be necessary for a deviation from or a change in the engineering drawing.

M3500 Bolt and Stud Standard includes an M3500C medium-carbon cold-worked hex-head bolt of Bhn 207-269, minimum tensile strength of 110,000 psi and minimum proof load of 85,000 psi. It specifies SAE 1038, 1040, 1042, and 1043 as approved steels and requires no heat treatment. As optional it permits

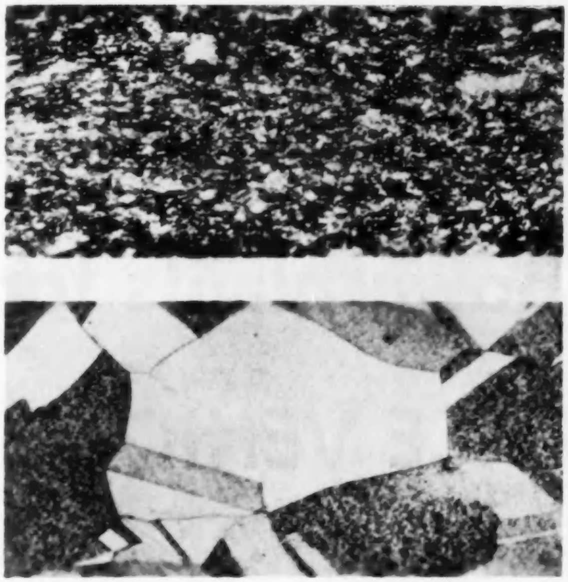

Fig. 5 — Microstructures of radiator tube brass: annealed to temper (top) and rolled to temper (bottom).

heat-treated bolts made of SAE 1041, SAE 1046, or alloy steel of 0.30–0.45% carbon. The optional bolts would be used only if found economical or during shortages.

M3431 Steel Tubing Standard groups four different construction brazed and welded tubes, coated in various ways and uncoated. Fig. 8 shows the various constructions: type 1, brazed single strip — double wall; type 2, brazed double strip — double wall; type 3, butt brazed or welded — single wall; and type 4, bevel brazed — single wall. A table in the standard indicates the application options. The remainder of the standard indicates bursting strength requirements, coating weights, hardnesses, and bending requirements.

HT 4-1 Deep Case Carburizing and Hardening Standard was developed to permit alternate methods of carburizing and outline acceptable processes without itemizing them on the drawing. It covers such items as:

1. Carburizing methods and temperatures.
2. Quenching rates, oil temperatures, and oil viscosities.
3. Reheating procedures, if needed.
4. Tempering requirements.
5. Case depth measurement and limitations on grinding.
6. Carbon concentration of case.

The use of this standard has greatly simplified drawing specifications. A typical requirement reads:

Carburize	0.040–0.050 in. as per HT 4–1
Core Bhn	229–302
Surface	Rc 60 minimum–file hard

Similar standards are developed for such diverse applications as wrought brass, stress relieving wire springs, painting, electroplating, and light case carburizing.

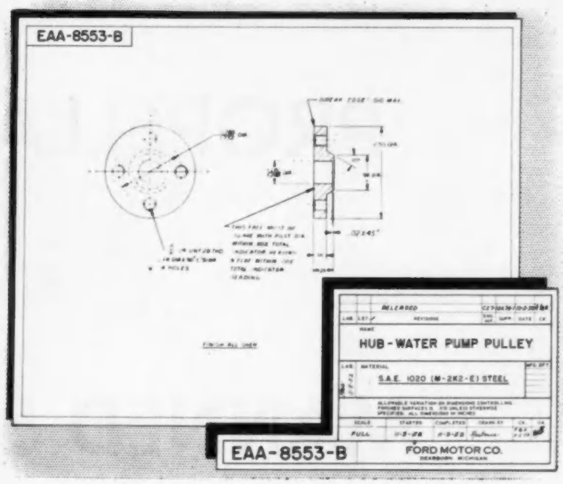

Fig. 6 — Material specification of water pump alloy hub.

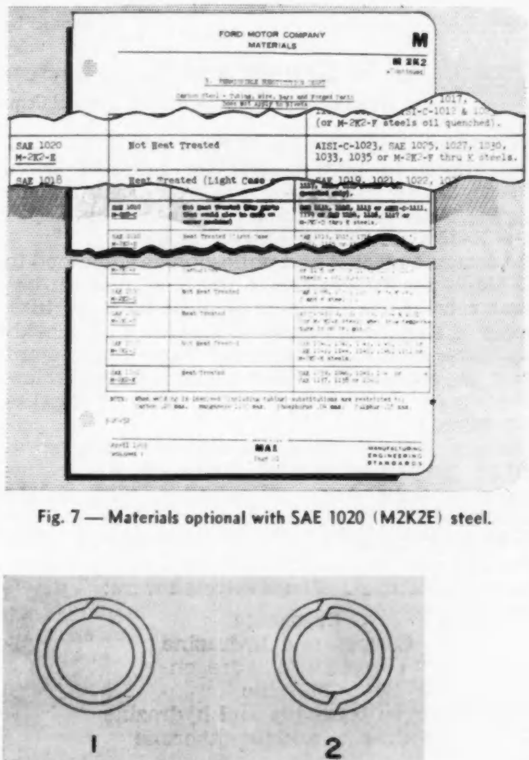

Fig. 7 — Materials optional with SAE 1020 (M2K2E) steel.

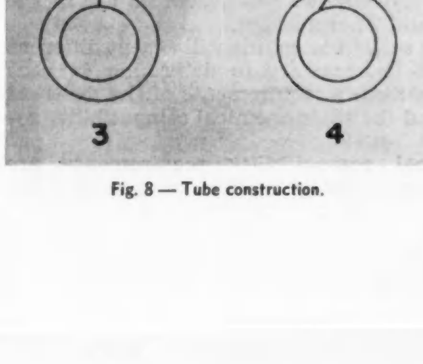

Fig. 8 — Tube construction.

PROPELLANT substitutions in powerplants for MANNED SPACE VEHICLES

Based on paper by

G. R. Cramer and H. A. Barton

Reaction Motors Division, Thiokol Chemical Corp.

UNUSUAL possibilities result from propellant substitutions in powerplants for manned space vehicles. These possibilities are well illustrated by using the XLR-99 turborocket engine as developed for the X-15 aircraft as the basis for a study.

The design concepts and philosophies combined in the XLR-99 for application in the X-15 play an important role in the propellant-substitution picture. Because of them, the engine is forgiving of considerable abuse caused by wide variations in propellant and vehicle conditions. (This ruggedness and tolerance contrast sharply with the nature of missile-type engines.)

Reaction Motors engineers selected four representative propellant combinations for illustrative purposes in their study of propellant substitution possibilities. The particular four were selected because of their compatibility with the present XLR-99 engine . . . and because of their desirable performance characteristics. Those selected were:

Cryogenic
Oxygen and hydrazine
Oxygen and hydrogen
Storable
Nitrogen tetroxide and hydrazine
Hydrazine and pentaborane

Fig. 1 shows how these selected combinations compare with liquid oxygen and RP-1 (a specially controlled grade of jet fuel). This propellant combination is perhaps best known from its use in the Atlas, Titan, and Thor missiles.

To find how easily the engine will accept different propellants, it is necessary to determine (a) the physical compatibility requirements of the different propellants and (b) their chemical compatibility requirements.

The physical compatibility requirements are needed to permit determination of whether the pumps possess adequate flow capacity and can produce a sufficient head rise; what the turbine power requirements are; what the system pressure drops will be; and how well the thrust chamber will be cooled.

The chemical compatibility requirements permit determination of what materials must be changed and/or what protective measures must be provided for the engine materials and/or the propellants.

Together, they give a sound base for determining the relative ease of making any given substitution . . . and for determining the gains to be realized.

The required chemical compatibility modifications are also relatively minor. These involve changing some elastomers used as seals and substituting an aluminum casting alloy for the present magnesium pump housings. No changes in basic design concepts are required.

Results of specific propellant substitutions can be viewed in terms of a few significant parameters, such as specific impulse, density, impulse, thrust, and thrust-to-weight ratio. To put these comparisons on a convenient basis, the nozzle area ratio was increased to 30 — by means of a simple nozzle extension. Also, free space operation was assumed.

O_2-N_2H_4 combination

First considered was the O_2–N_2H_4 combination. (The hydrazine was modified with an additive (10% bw) to increase thermal stability)

Physical Changes — The very favorable mixture ratio and density relationships of the oxygen-hydrazine combination plus a higher energy release allow this propellant substitution to be accomplished with only very minor changes. The fuel impeller is trimmed slightly because of the higher fuel density, and the system orifices are adjusted for proper mixture ratio and performance level. (Orifice adjustment is common to all the substitutions described here, and will not be mentioned again.)

The excellent coolant properties of hydrazine plus a higher weight flow rate provide excellent thrust chamber cooling over a wide throttling range.

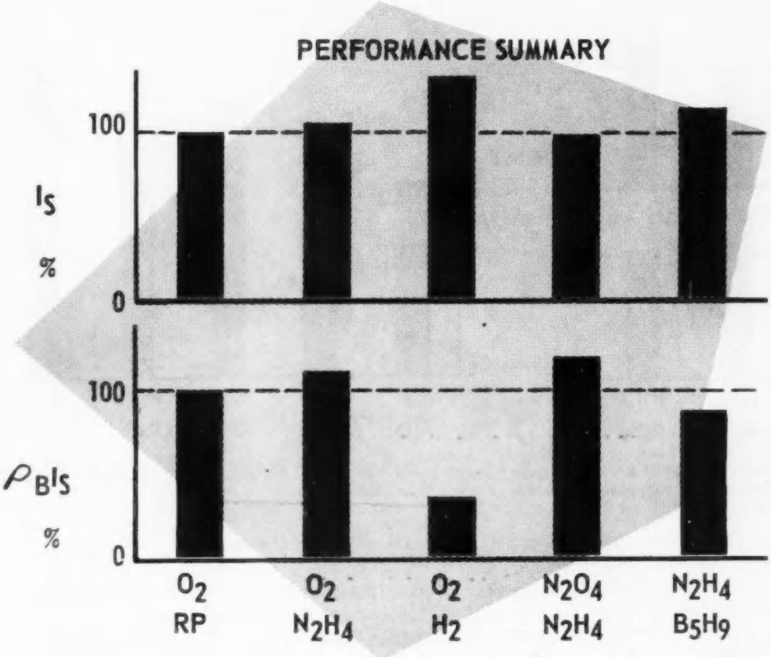

Fig. 1 — How selected propellant combinations compare with liquid oxygen and RP-1 (a specially controlled grade of jet fuel).

Chemical Changes — Since the oxidizer is unchanged, the fuel presents the only consideration. Known effects of the hydrazine on the existing fuel system materials reveal the need to switch the magnesium fuel pump casting to aluminum, and to substitute compatible materials for some of the elastomers used for seals in the fuel system. Certain bearings used in the propellant control valves require a simple substitution to avoid corrosion. However, all other metallic parts are compatible with hydrazine.

Adequate cleanliness is the only other primary concern in the fuel system. This is necessary to prevent unnecessary decomposition of the hydrazine.

Results — As can be seen, the O_2–N_2H_4 system fits the engine well; but what does the substitution do for us? The answer follows:

O_2–N_2H_4 Substitution

Specific Impulse	322
Density Impulse	348
Max Thrust	62,300–91,500

(Based on 30/1 area ratio in free space)

Specific impulse is increased by approximately 6% and density impulse by 27%.

Thrust is essentially unchanged, since this substitution can be accomplished without changing chamber pressure. Thrust-to-weight ratio is not visibly affected, since the only pertinent change was a slight weight increase due to the fuel pump casting material switch.

Next, suppose an increase in the propellant flowrates to the full volumetric capacity of the existing pumps — and then a slight enlargement of the thrust chamber throat to accept the higher weight flow without changing chamber pressure.

The engine now produces a thrust of nearly 92,000 lb!

This is an increase of 48% without sacrificing the manned rating safety factors. A slight weight increase results from the requirement of beefing up the thrust mount structure, but it is small as indicated by the thrust-to-weight ratio, which jumps 46%.

O_2-H_2 combination

The next cryogenic, O_2–H_2 is another example of a fuel substitution. There are several characteristics of hydrogen, however, that make it a distinctly different substitution than hydrazine:

1. Performance (specific impulse) with O_2 is 30% higher.
2. Density is *less than 10%* of N_2H_4.
3. As a coolant, it far surpasses N_2H_4, despite the fact that H_2 is a cryogenic with a boiling point approximately 650 F below that of N_2H_4.

The physical and compatibility changes required to accommodate this energetic propellant combination follow:

Physical Changes — The low density of hydrogen requires a threefold increase in pump volumetric flow capacity and in peripheral velocity to generate the required pressure rise. Perhaps there is a question in your minds about increased fuel system pressure drops accompanying the very large increase in volumetric flowrate. Here the extremely low viscosity of hydrogen assumes a star role. Despite relatively high velocities, pressure drops are actually lower than those in the current ammonia system.

Chemical Changes — Cold though it is, hydrogen is easy to get along with. All of the *metallic* materials in the present XLR-99 fuel system are compatible with hydrogen and vice versa. On the other hand, most of the elastomers would shrink and harden, allowing liquid hydrogen leakage. Simple material substitutions here will eliminate this pos-

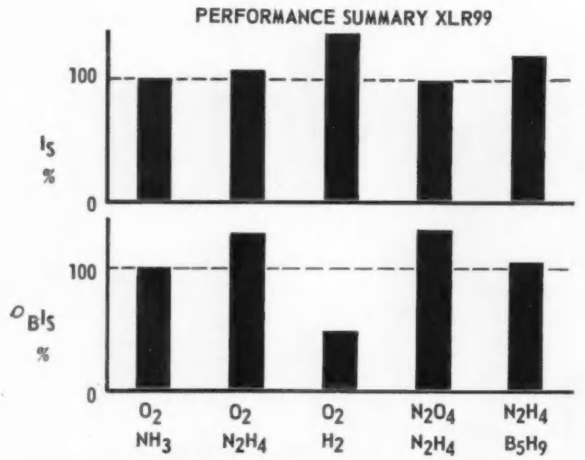

Fig. 2 — A wide range of specific impulse and density impulse is available from a single basic engine, using only the four sample propellant substitutions.

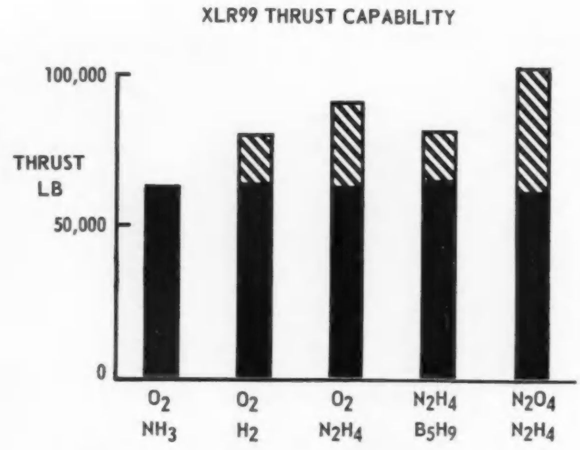

Fig. 3 — Shown is the major effect of four different propellant substitutions in terms of thrust capability.

PROPELLANTS for MANNED SPACE VEHICLES

. . . continued

sibility. However, as with hydrazine, system cleanliness is an especially important factor.

Results — Although the O_2–H_2 system requires an extensive modification of the fuel pump, the dramatic results show this to be worth while.

O_2-H_2 substitution

Specific Impulse	421
Density Impulse	135
Max Thrust	64,000–80,000

(Based on 30/1 area ratio in free space)

Specific impulse is increased 38% over the O_2–NH_3 system.

Density impulse is drastically reduced to one-half that of the O_2–NH_3 system.

Thrust will be essentially unchanged (62,000 lb) if chamber pressure is held constant. If we choose to increase the flow rates and enlarge the chamber throat slightly (as in the first example) we can raise the thrust level to 80,000 lb.

Thrust-to-weight ratio is not significantly altered at the 62,000-lb thrust level but will jump sharply by 28% at the higher thrust level.

N_2O_4-N_2H_4 combination

The first of the storable propellant category is N_2O_4–N_2H_4. This combination introduces a new consideration because it involves a substitution of both oxidizer and fuel, which is hypergolic. This permits some simplification in the igniter, which then takes on the role of a pilot stage.

In this role it provides the initial reaction in the chamber at safe, low mass flow rates, and insures consistently smooth buildup of thrust. Also, the pilot stage provides a hot gas purge of the main chamber both on start and upon shutdown, as it now does in the present engine.

Other considerations involved in substituting the storable N_2O_4–N_2H_4 combination in the XLR-99 follow:

Physical Changes — The favorable mixture ratio, performance level, and density relationships of this combination result in volumetric flow rates for both propellants about 25–30% below those of the existing oxygen-ammonia system. Thus, the new fuel and oxidizer are easily accommodated in the present pumps. Since both propellants are more dense, adequate pressure rise is easily provided. In fact, both impeller diameters must be trimmed slightly if rotational speed is held constant.

Chemical Changes — Compatibility requirements necessitate changes to both the fuel and oxidizer system, involving the use of aluminum pump castings, new elastomer seals, and adequate cleanliness.

Results — What does this substitution provide compared with the oxygen-ammonia system? The following is a summary of this information.

N_2O_4-N_2H_4 substitution

Specific Impulse	300
Density Impulse	356
Max Thrust	62,000–102,000

(Based on 30/1 area ratio in free space)

Specific impulse is about the same, but the convenience of storability is provided.

Density impulse, however, is increased about 30%.

Thrust level (maximum) is essentially the same. However, the maximum thrust level can be increased by 65% (to over 100,000 lb) by utilizing the full flow capacity of the existing pumps and increasing the chamber throat size slightly. The thrust-to-weight ratio then rises sharply by over 60%.

A second storable combination is N_2H_4–B_5H_9 — the last substitution to be covered in this discussion.

This combination — the so-called B/N system — introduces an odd factor. The hydrazine, formerly accepted as a fuel, now puts on a new hat to become

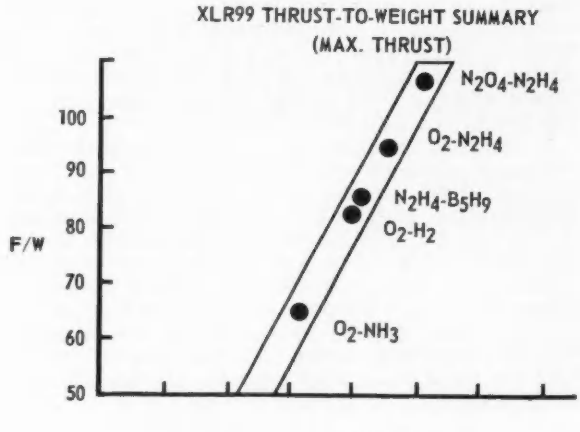

Fig. 4 — A drastic increase can be realized in engine thrust-to-weight ratio (at maximum thrust) — as a byproduct of propellant substitutions.

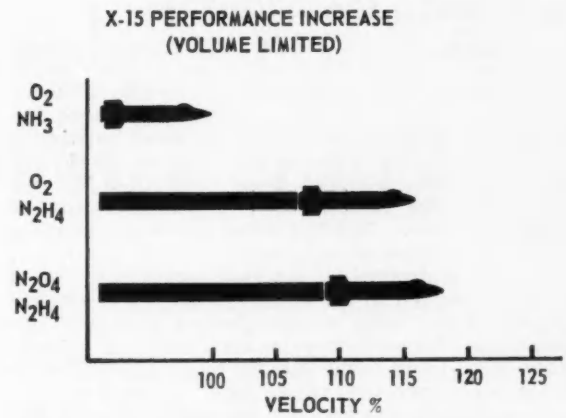

Fig. 5 — Propellant substitutions without tank modifications yield a significant increase in maximum speed capability.

the oxidizer! The reason for this is that the nitrogen (from the hydrazine) forms a nitride of the boron in much the same way that oxygen or fluorine combine with fuel elements.

Despite this switch in role, the hydrazine can be substituted in the current ammonia system (as in the other N_2H_4 substitutions) and the pentaborane placed in the current oxidizer system.

Physical Changes — The mixture ratio and performance level of N_2H_4–B_5H_9 act to yield volumetric flow rates that are less than the present oxygen and ammonia. However, to provide sufficient pressure rise with the less dense B_5H_9, the pump impeller must be used at its maximum diameter (that is, untrimmed) whereas the N_2H_4 pump impeller must be trimmed slightly.

Although labeled an "oxidizer" here, the hydrazine is available in sufficient quantity to serve as the coolant. (The demands on the coolant system are less than those in the O_2–N_2H_4 or the O_2–NH_3 systems because the combustion temperature is comparatively low.)

Chemical Changes — The changes required to accept the hydrazine need not be reiterated. The B_5H_9 requires replacement only of certain elastomers, since the metallic components are generally compatible. Adequate cleanliness is again required primarily to eliminate oxides from the system.

Results — As shown below, this energetic propellant combination provides storability plus high performance.

N_2H_4-B_5H_9 substitution

Specific Impulse	362
Density Impulse	285
Max Thrust	65,400–82,000

(Based on 30/1 area ratio in free space)

Specific impulse is 19% greater than for O_2–NH_3 (and N_2O_4–N_2H_4).

Density impulse is 4% greater than for O_2–NH_3 (but 20% less than for N_2O_4–N_2H_4 because of the lower bulk density).

Thrust is up slightly from the 62,000-lb level and reaches somewhat over 65,000 lb at constant chamber pressure because of the lower expansion exponent for the exhaust products.

If the full-flow capacities of the pumps are again utilized as in the other examples, thrust is increased 25% to 82,000 lb. Thrust-to-weight ratio at the increased thrust level then jumps by 30%. As in all the other cases, the manned rating safety factors and full control features are retained without a commensurate weight penalty.

Interpretation

Fig. 2 shows the wide range of specific impulse and density impulse available from a single basic engine using only these four sample propellant substitutions. There are other propellant combinations in less advanced stages of development. It is clear that these improved propellants, such as the OBF system (fluorinated oxidizers and boron fuels), will permit continued extension of the performance regimes as illustrated.

Fig. 3 shows the major effect of the sample substitutions in terms of thrust capability. This significant picture stems in part from the propellant characteristics but, to a larger degree, from the inherent engine characteristics.

And finally, Fig. 4 recalls the drastic increase in engine thrust-to-weight ratio (at maximum thrust) which can be realized as a byproduct of the propellant substitutions. This would be equivalent to increasing the thrust of a JT4A-11 turbojet from 17,500 lb up to 29,000 lb without changing its weight. (Even at the higher thrust level the turbojet would have a thrust-to-weight ratio of only 5.7).

Now what does all this mean? Perhaps the simplest way to appreciate the propellant substitution results is by means of a few simplified manned space vehicle mission examples, including both volume-limited and nonvolume-limited propellant-tank types. For something reasonably familiar, let's take the X-15 aircraft as a starting point.

Because it is in existence today, the X-15 can be considered a propellant-tank volume-limited case when we think about making propellant substitu-

PROPELLANTS for MANNED SPACE VEHICLES

. . . continued

tions *without tank modifications.* As Fig. 5 shows, substitutions on this basis yield a significant increase (16–18%) in the maximum speed capability and hence exploration capability of the X-15 air launched from a B-52. Note that O_2–N_2H_4 and N_2O_4–N_2H_4 give approximately equal performance advantages here. But the latter provides the additional advantages of storability.

In Fig. 6 droppable auxiliary propellant tanks have been added to the X-15. This gives a *weight-limited* rather than volume-limited case and the advantage of specific impulse and additional propellants is striking — the thrust uprating capability becomes an important factor here. Aircraft thrust-to-weight ratio can be held constant, allowing initial acceleration to be maintained and gravity losses to be minimized.

Now, assume the droppable auxiliary propellant tanks are retained, but the X-15 is placed on top of a typical missile for a ground launching. Now, as Fig. 7 shows, the X-15 has an orbital capability (using the B/N system as an example). Again, the thrust uprating capability allows selection of the most desirable initial acceleration, despite the increased weight of the additional propellant load. With throttling, acceleration can be easily controlled during the entire flight and controlled maneuvering is also effectively accomplished, even after most of the propellant load is consumed.

In the final example, an advanced manned space vehicle is assumed, which is not propellant-volume limited. Here are higher performance propellant substitutions in both the cryogenic and storable categories: the B/N storable system and the O_2–H_2 cryogenic system. Fig. 8 shows the significant advantages of these substitutions in two ways: increased orbital aerospace craft payload, and increased total velocity capability of the manned vehicle. Both cases assume the same booster vehicle and the same gross weight for the booster plus orbital vehicle.

Conclusions

Propellant substitutions make available an unusually wide range of performance capabilities from one basic, fully developed engine design.

Future manned space vehicle types and functions will similarly span a wide range of performance requirements. The vehicle designers and planners will thus have available to them a broad spectrum of engine characteristics to select from for each mission. This eliminates the need for many completely new engine systems and the financing of the vast sums usually necessary for new engine development programs.

The capability to accommodate numerous propellant substitutions without costly major redevelopment programs and the inherent attribute of universal application serve to reduce substantially the financial burden upon the national space effort. The result of this is that more emphasis can be placed upon the actual space operation.

Many propellant substitutions can be accomplished in the XLR-99 without compromising controllability, the high reliability, or the manned safety rating, and without expensive redevelopment. This is made possible primarily because of the design concepts and philosophies developed over many years to meet the propulsion requirements of manned space vehicles.

To Order Paper No. 177C . . .
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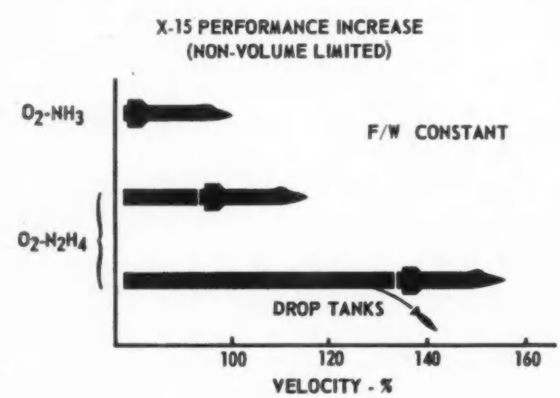


Fig. 6 — Addition of droppable auxiliary propellant tanks (which gives a weight-limited situation) yields a striking increase in maximum speed capability.

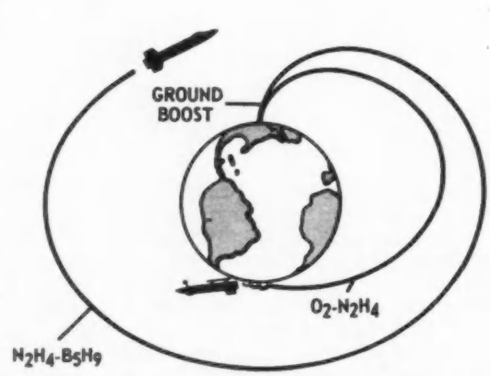


Fig. 7 — Orbital capability of X-15 (with drop tanks).

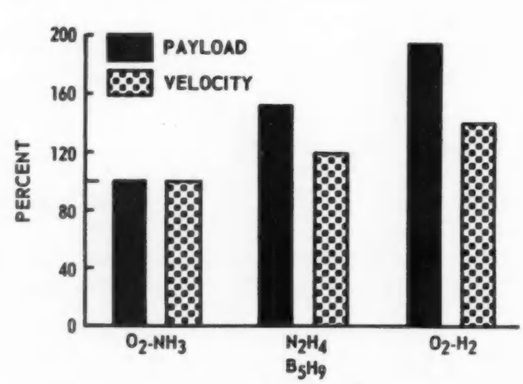


Fig. 8 — Orbital payload and velocity advantages.

Computer solves complex suspension geometry problems

It proves to be an efficient tool for determining precise locations of pivot points for a front or rear suspension that would provide all desired geometry features as well as proper spring characteristics.

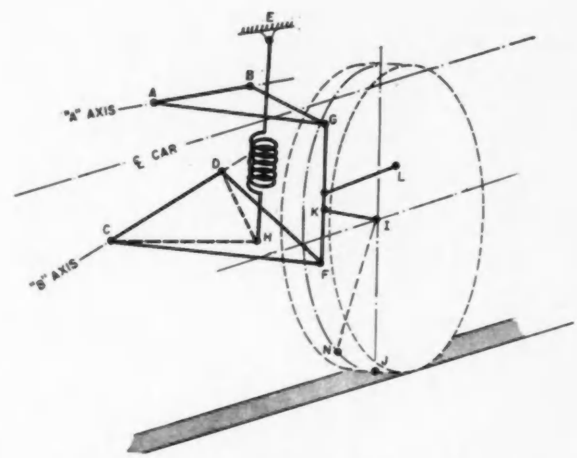


Fig. 1 — Left front suspension showing fixed distance relationship between points.

Based on paper by

Kenneth L. Hoyt, Charles F. Maddox, Norman R. Miller, and Donald F. Zawada

Engineering Research and Advanced Product Study Office, Ford Motor Co.

PROGRAMMING on a computer proved essential to establish the suspension goemetry of a double-wishbone front suspension for a low-frequency spring medium. Only in this way could the determination of the spring-to-wheel relationship be made with sufficiently accuracy.

The importance of the rate of change of ratio between the springing medium and the wheel travel for low-frequency suspensions made it mandatory to rely on the computer for a proper solution of this problem. The program was subsequently generalized to be applicable to either front or rear suspensions and to permit variations in spring medium type.

Double-wishbone front suspension

The double-wishbone front suspension, shown schematically in Fig. 1, differs very little from the conventional double-wishbone type now in use on many passenger cars. The suspension consists of an upper arm, which pivots around axis A, a lower arm, which pivots around axis B, and a wheel spindle, which is connected to the upper and lower arms by ball points at points *G* and *F*. The upper arm is attached to the frame at points *A* and *B*, and the lower arm is attached to the frame at points *C* and *D*. The springing medium is attached to the lower arm at point *H* and to the frame at point *E* by pivots. Point *L* is the steering arm pickup point, which controls the steering of the vehicle by moving the wheel spindle around the kingpin axis.

The data necessary from the computer to evaluate double-wishbone suspension geometry are:

1. Paths in three dimensions of upper and lower suspension ball joints.
2. Wheel center path.
3. Path of tire-to-ground contact point with wheel rolling as well as braked.
4. Path of lower attachment for springing medium.
5. Spindle steering arm ball joint path.
6. Camber change in degrees.
7. Caster change in degrees.

These data allow the evaluation of the characteristics of the front suspension. The path of the upper and lower suspension ball joints determines the camber and caster change. The path of the tire-to-ground contact point, with the wheel rolling, determines the roll center and the tread change. The path of the tire-to-ground contact point, with the wheel braked, determines the antidive characteristics and the path of the steering arm ball joint enables an engineer to locate an inner tie rod point that will give zero wheel fight in a straight-ahead position.

Without outboard mounted brakes, the antidive

characteristic depends on the path of the ground contact point in the side view (Fig. 2) and the angle β between the tangent to this path and a vertical line. The path of the ground contact point is established under the assumption of a blocked wheel with regard to the brake backing plate.

The ground contact point has to move forward in jounce travel and rearward in rebound travel to provide positive antidive. The per cent of antidive can be varied by adjusting the geometry to change the angle the tangent to the path of the ground contact point makes with a vertical line.

In setting up the computer program, the task of devising a method for computing the paths of the various points on the suspension was simplified by the fact that it was not necessary to write equations describing the complete paths followed by the points. It was merely necessary to find a means for computing the position of each point when the wheel, or some other component, was moved into a specified position. To accomplish this, the complex movements of the several components relative to the frame (which was considered to be fixed in space) were broken down into a series of simple movements of each component relative to the components to which it was attached.

Equations were written describing the simple motion of each point. The order of solution of these equations was arranged so that the locations of the various points on the suspension could be computed one at a time, in sequence, rather than simultaneously. The order in which the points were located is shown in Fig. 3, which is the flow chart of the program used to solve the equations. In this particular problem, constant steering angle was specified, and it was not necessary to write equations for the steering linkage.

The design locations (referred to a set of coordinate axes) of various points and axes on the suspension with the wheel at the zero jounce position, and various constant quantities, such as the rolling radius of the wheel, were given as input data. The fixed distances between points connected by rigid members and fixed angles between straight lines connecting pairs of such points were then computed from the given data. From the values thus obtained, the constants of the equations of the points on the suspension were computed.

With these preliminary operations completed, the solution of the major portion of the problem, the determination of the locations of the points and the computation of other data of interest for various conditions of jounce and rebound, could begin. First to be located was point F, the outer ball joint on the lower arm (Fig. 1).

This point was chosen as the starting point of the solution because it moves in a fixed plane, which is perpendicular to a known axis, and its location with respect to two of the coordinate axes can be found easily and directly when its location with respect to the other is specified. The problem would have been more difficult to solve had the wheel center, or some other point on the wheel or wheel hub, been used as the starting point. For this reason, the particular jounce or rebound position of the wheel for which each solution was obtained was not specified at the start, but rather was solved for as one of the unknowns in the problem. The locations of the

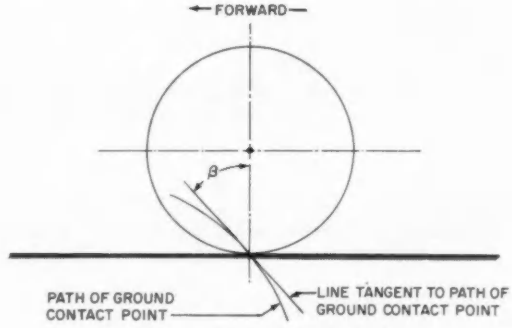


Fig. 2 — Side view of front wheel.

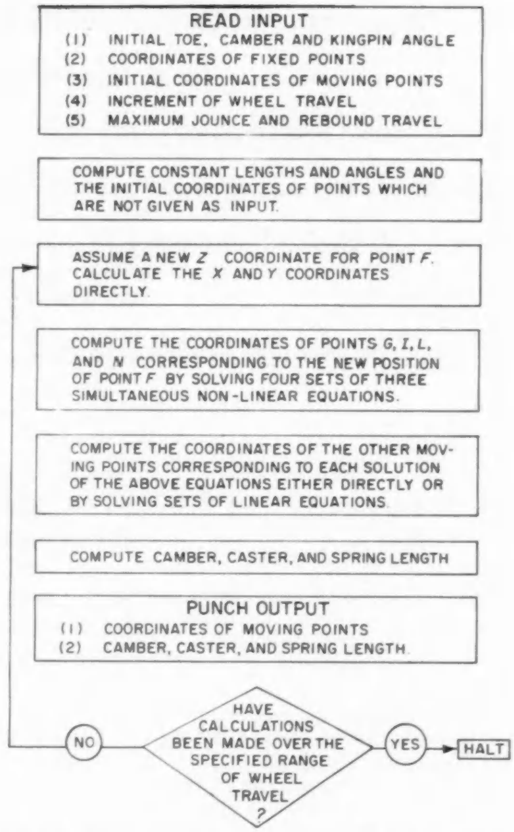


Fig. 3 — Flow chart of complete program used to solve equations.

various points on the suspension were computed as functions of point F, but plotted as functions of wheel position.

Point F rotates around the swing axis (axis B), on a circular path described by three equations devised by using a mathematical equivalent of the method of solution used on the drafting board. In this method, auxiliary views are made to show a normal view of the circular path, and the location of any point on the path with reference to the coordinate axes is obtained by projecting points back from the normal view. The equations obtained in this manner were linear and independent, since the location

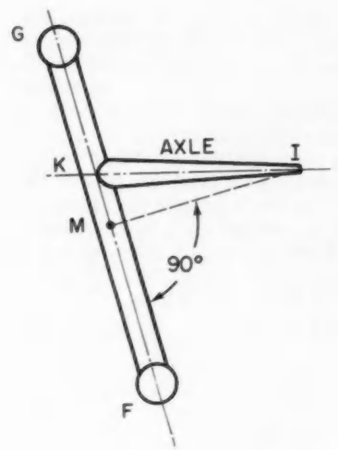


Fig. 4 — Normal view of kingpin and axle.

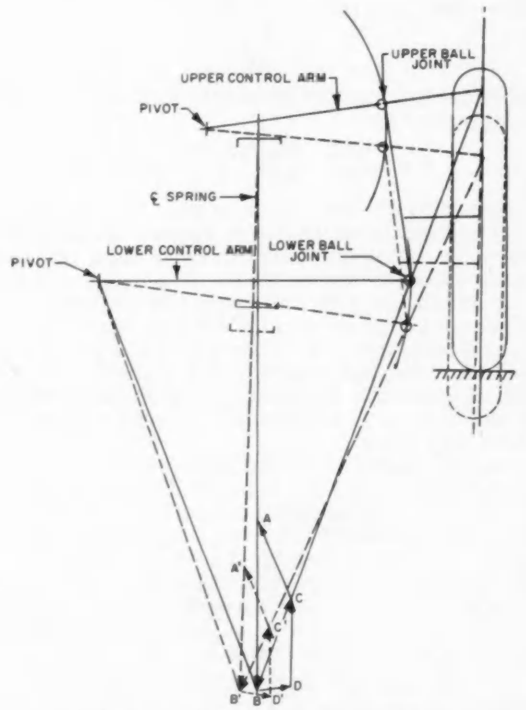


Fig. 5 — Geometric ratio effect on wheel loads.

of the B axis in space was known, and they were easily programmed for solution on the computer.

In starting a solution, the height of point *F* above a horizontal reference plane was changed by a predetermined amount. With the new height of *F* known, the equations of the path of this point were solved to give the new location of the point in space.

Point *H*, at the lower end of the spring, rotates around the B axis on a circular path in exactly the same manner as does point *F*, and hence the path of *H* is described by equations identical in form to those of point *F*. If an end view is taken of the B axis, it will be noted that a constant angular relationship is maintained by straight lines connecting points *F* and *H* to this axis. Knowing the locations of the axis and point *F*, and having previously calculated the magnitude of the angle involved from the data given initially, the engineer could readily solve the path equations for the location of *F*.

Point *G*, the outer ball joint on the upper arm, rotates around the A axis in the same manner that *F* and *H* rotate around the B axis. Furthermore, point *G* is always a fixed distance, the length of the kingpin, from point *F*. Thus, three linear equations were written to describe the circular path of *G* and one nonlinear equation was written to describe the fixed distance relationship, and these were solved simultaneously to give the new location of *G*.

With the ball joints *F* and *G* located, the position of the kingpin axis in space was also known. In this particular problem, the axle and kingpin intersect at an angle which is somewhat different from 90 deg (Fig. 4). The point *K*, at which the centerline of the axle intersects the kingpin axis, and the point *M*, at which a perpendicular from the wheel center intersects the kingpin axis, are always located fixed distances from the ends of the kingpin. A set of linear equations describing this relationship was easily solved for the positions of points *K* and *M*, once the location of the kingpin was known. A linear equation was written which related the location of the wheel center (*I*) with respect to two of the three coordinate axes to the steering angle and the position of point *K*. A second linear equation described the fact that point *I* is located in a plane which is perpendicular to the kingpin axis at point *M*. Point *I* is always a fixed distance from point *G*, and this relationship was described by a third, nonlinear, equation. Simultaneous solution of the three equations located point *I*.

Points *L*, the spindle steering arm ball joint, and *I* rotate around the kingpin axis with a fixed angular separation in the same manner that points *F* and *H* rotate around the lower arm swing axis (B). Thus, point *L* was located in a manner similar to that used to locate point *H*.

Point *J* lies in the center plane of the wheel and is always in contact with the ground. A straight line connecting this point with the wheel center, point *I*, is equal in length to the rolling radius of the wheel, is perpendicular to the axle, and, together with the axle, forms a plane which is always perpendicular to the ground plane. Three equations expressing these relationships were solved to give the position of point *J*.

N is a point on the tire lying in the center of the patch area when the wheel is in the zero jounce position. This point moves off of the ground when the locked wheel rotates slightly as the suspension moves. Point *N* is always a fixed distance from points *F*, *G*, and *I*. The position of point *N* was obtained by solving three equations describing the fixed distance relationships. Because these equations were nonlinear, involving the squares of the various unknown quantities, this solution was performed by using the Newton-Raphson method, an iterative method in which the equations are expanded by Taylor's theorem and the change of each variable from its last computed value is found by successive approximations.

With the locations of the various points on the suspension for a given height of point *F* above the

reference plane determined, the camber of the wheel, the change in spring length, and other data of interest were readily computed. In this manner, the height of point F was varied in discrete steps and the required data was computed and plotted.

The computer solution of this problem required about 30 min running time to obtain results throughout plus and minus 5 in. of wheel travel in ½-in. increments. Involved were 80 equations, one-half of which were used to compute initial constants and one-half to determine the coordinates of the moving suspension points at each position of jounce or rebound travel. The short time required made it possible to run numerous solutions for variations of the same basic geometry, one of which had just the characteristics desired.

After a final design was chosen, the effect of variations in dimensions allowable within production tolerances was checked and indicated that the desirable characteristics of the suspension could be maintained in mass production.

Numerical plots of data obtained from the computer were later compared with measurements made on the suspension when it was installed in a car, and the two sets of data checked very closely. This substantiated the check that was made on the variations in dimensions due to buildup tolerances.

Wheel rates for l-f independent suspensions

The lowering of wheel rates to attain undamped frequencies in the range of 30–40 cpm has led to difficulties not previously encountered in conventional suspension systems, with frequencies of 65–75 cpm.

Wheel rates measured on the vehicle have generally varied slightly from the calculated wheel rates, based on the assumption that the wheel rate is approximately equal to the spring rate multiplied by the square of the ratio of spring travel to wheel travel.

However, experience with low-frequency springs installed in a conventional front suspension indicated that failure to correct for geometric ratio changes actually can result in negative wheel rates in rebound travel. In substantiation of these findings, a vectorial analysis of a particular low-frequency front suspension disclosed that the load at the wheel had *increased* by nearly 600 lb from design position to full rebound, indicating the effective rate at the wheel had become negative.

Fig. 5 is a graphical illustration showing the effect of the geometric ratio on the forces involved in a typical front suspension. If AB represents the spring load at a given wheel position, then AC is the force on the lower-control-arm inner pivots, BC is the force on the lower-control-arm ball joint, BD is the compression force on the upper control arm, and CD is the wheel load. As shown in the figure, if the wheel is moved to some other position and the force diagram is again constructed, the geometric changes affecting the ratio of spring load to wheel load can readily be interpreted by comparing $A'B'$ with AB and $C'D'$ with CD. Applications of this system to various proposed low-frequency suspensions, where the change in spring load is slight per increment of wheel travel, indicate negative wheel rates when $C'D'$ in rebound is greater than CD in the design position.

Effective as this graphical system is, its application to front suspension systems where the control arms are swept back or placed at odd angles to obtain "anti" features or other desired suspension properties is inappropriate, since the centers of rotation would no longer be true centers.

Rather than employ complicated drafting methods, an analytical solution was used in which the wheel rates were found for each jounce and rebound position by making use of the fact that the work performed in moving the wheel vertically is equal to the work performed in changing the length of the spring or other force-producing member. Thus:

$$L_w dY = L_s dX \qquad (1)$$

where:

L_w = Wheel load
L_s = Spring load
X = Change in spring length from design length
Y = Vertical travel of tire-to-ground contact point from design position

The wheel rate (K) is defined by:

$$K = \frac{dL_w}{dY} \qquad (2)$$

Combining these two equations gives a more useful expression for K:

$$K = L_s \frac{d^2X}{dY^2} + \frac{dL_s}{dX}\left(\frac{dX}{dY}\right)^2 \text{lb per in.} \qquad (3)$$

Attempts were then made to use the values of X and Y, as measured from the suspension geometry layout, for fitting an empirical polynomial equation to establish a functional relationship between X and Y, by which the first and second derivatives of X with respect Y could be calculated for use in the expression for wheel rate. However, it was soon found that, due to the complexity of the modern front suspension geometry, the most careful drafting methods did not give the accuracy required to obtain satisfactory results.

The inadequacy of conventional methods for obtaining exact values for X and Y directed attention to computer techniques made available by the successful completion of the front suspension program.

With accurate values for X and Y, a supplementary program was written for the computer in which derivatives of spring length with respect to wheel travel in equation (3) were determined after equating X to a polynomial expansion of Y:

$$X = a_1 + a_2 Y + a_3 Y^2 + a_4 Y^3 + \ldots + a_n Y^n \qquad (4)$$

The constant coefficients $a_1, a_2, \ldots a_n$ in equation (4) were found by using the computed values of X and Y as input data for a least-squares type of curve fitting program.

In making the curve fits, the arbitrary decision was made to determine fitted polynomials up to the maximum of the tenth degree. For each degree of polynomial, the curve fitting program provided eight significant digits in each of the coefficients; and for each set of coefficients provided a set of computed values of X for the given values of Y, and the error between the given value of X and the computed value of X. The 10 sets of error values were compared to determine the degree of the polynomial for which the computed values best ranged from the fourth to the tenth in various instances, but seventh

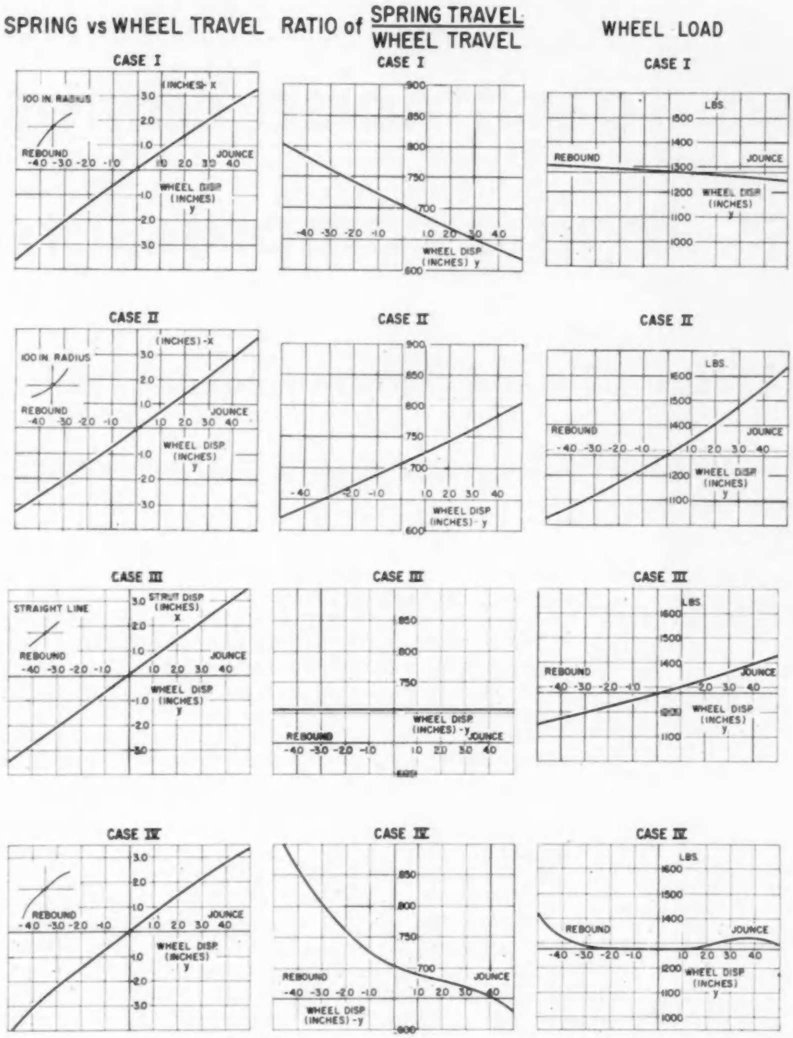


Fig. 6 — Curves for spring versus wheel travel, ratio of spring travel/wheel travel, and wheel load for four cases.

degree polynomials predominated. Since the spring load (L_s) was a known function of the spring length, the derivative of spring load with respect to spring length was found analytically.

With given values of X and Y, the coefficients of the chosen degree polynomial, and the constants required to compute the derivative of L_s, the computer program computed the value of dX/dY, $(dX/dY)^2$, and d^2X/dY^2 at each given value of Y, and then computed the values of spring load, spring rate, wheel rate, and wheel load for each value of X. Running time on the computer was 20 min for about 40 values of wheel travel.

It was then possible to plot curves for rate versus deflection and load versus deflection and to determine from inspection of these curves whether or not the suspension system possessed the desired stability; that is, positive wheel rates throughout the range of wheel travel.

Fig. 6 shows (on the left side) strut versus wheel travel $x = f(y)$ curves for four cases. Note that these curves are similar in appearance, yet the curves showing the ratio of spring travel to wheel travel dy/dx are quite different, producing widely varying load versus deflection characteristics.

The problem of proper determination of wheel rates when low frequencies are the objective exists on all suspensions — particularly on independent suspensions. With this fact in mind, the digital computer program for solving spring and wheel loads and rates was tailored to apply to any independent front or rear suspension where low-frequency spring media may be employed.

A further complication arises whenever the spring medium involved is a gas, since changes in the velocity of the movement of the gas tend to cause the process involved in calculating the rates to vary from isothermal to adiabatic, resulting in a variety of wheel rates from the static to dynamic state. The program for computing spring rates and loads was then revised to allow the polytropic exponent (K) to vary from 1.0 to 1.4 to solve for dynamic as well as static wheel rates and loads.

To Order Paper No. 127A . . .
from which material for this article was drawn, see p. 6.

Aircraft approach noise comes from bypass engine compressors

White noise and discrete frequency noise can be closely predicted by compressor characteristics.

Based on paper by

F. B. Greatrex

Rolls-Royce Ltd.

APPROACH NOISE of current jet aircraft with engines throttled back has been causing as much disturbance to communities as has jet noise during take-off. This noise comes from the compressor and can therefore be calculated in terms of compressor characteristics.

Attempts to correlate approach noise of Rolls-Royce bypass engines with their compressor characteristics have been encouraging. There is no reason for bypass engine noise to be any worse than that of existing engines of the same thrust.

Is it jet noise?

Approach noise has a lot of discrete frequencies in it which are very irritating, but there is also a loud white noise component. The first point to consider, therefore, is whether this is still jet noise that we hear when the aircraft flies overhead on approach or whether it all comes from the compressor.

Measurements have been made of the noise from an Avon engine in a Canberra aircraft flying overhead at high thrusts, which have recently been extended down to the low thrust end of the scale. By using two engines together at approach rpm Rolls-Royce has been able to fly the aircraft over at about the same forward speeds as we have been able to do with one engine at high rpm.

Fig. 1 shows some of the results for 500 ft altitude. The line shows the variation of jet noise with relative jet velocity — around 6000 rpm the measured overall noise is 13 db above the jet noise, around 5000 rpm it is 27 db above. Clearly this is not jet noise.

Spectrum analysis

Fig. 2 shows typical traces of the variation of this noise with time as the aircraft flies overhead. The top trace is for overall noise, the second for noise in the top octave, and the third for noise in the $\frac{1}{3}$ octave centered about 5000 cps.

It can be seen that the white noise varies quite smoothly as the aircraft flies overhead but that the high frequency traces show a double peak — a first peak when the aircraft is overhead, and a second peak about 2 sec later.

The $\frac{1}{3}$ octave analysis uses a band width of $\pm 13\%$ in frequency; clearly with these discrete frequencies present a narrower band-width is needed and therefore an analysis has been made of the noise heard at various instants of time with some equipment having a bandwidth of $\pm 3\%$ (for db down on the peak) over the frequency range from 500 to 8000 cps.

The results are shown in Fig. 3 for times from $4\frac{1}{2}$ sec before the aircraft is overhead to $5\frac{1}{2}$ sec after it is overhead. It can be seen that the noise has the general characteristics of a white noise having a maximum intesity in the region around 600–800 cps, with a number of peaks superimposed on this.

Width of the peaks shown on this diagram is not a true measure of the sharpness of the peak of the actual noise. This is because of the finite band width of the analyser and because the rpm's of the two engines used during the tests were not exactly the same but were 2% apart.

It is quite clear, however, by actually listening to the noise, that true discrete frequencies are present. It is therefore fair to assume that the peaks on these curves represent at their peaks the magnitude and frequency of the discrete tones present.

Variation of noise with time

Variation of sound pressure level against time for the various components of the noise is shown in Fig. 4. The overall noise is taken directly from the trace and is shown rising to a peak about 1 sec after the aircraft has passed overhead, a peak of 87 db in this case when the aircraft was at 500 ft altitude.

In the lower part of Fig. 4 the lines are drawn for the calculated variation in frequency of notes emitted by the compressor as heard by an observer on the ground. The variation is, of course, due to

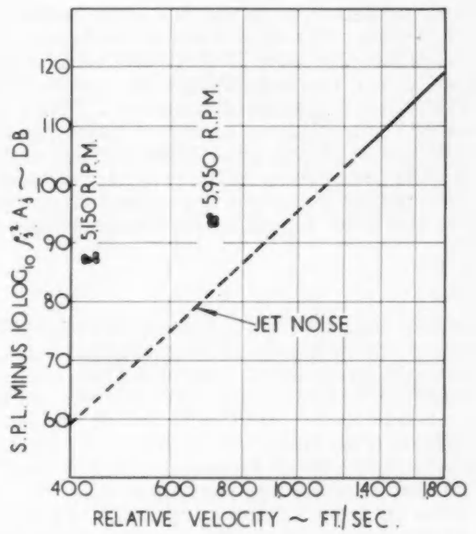


Fig. 1 — Overall noise measurements on approach at 500 ft.

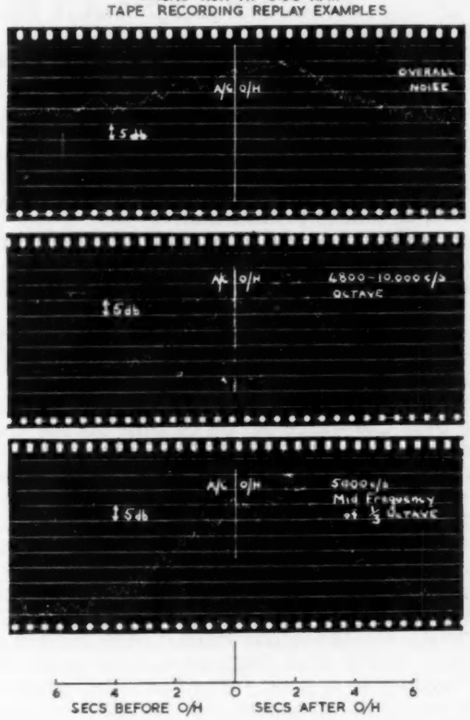


Fig. 2 — Variation of noise with time.

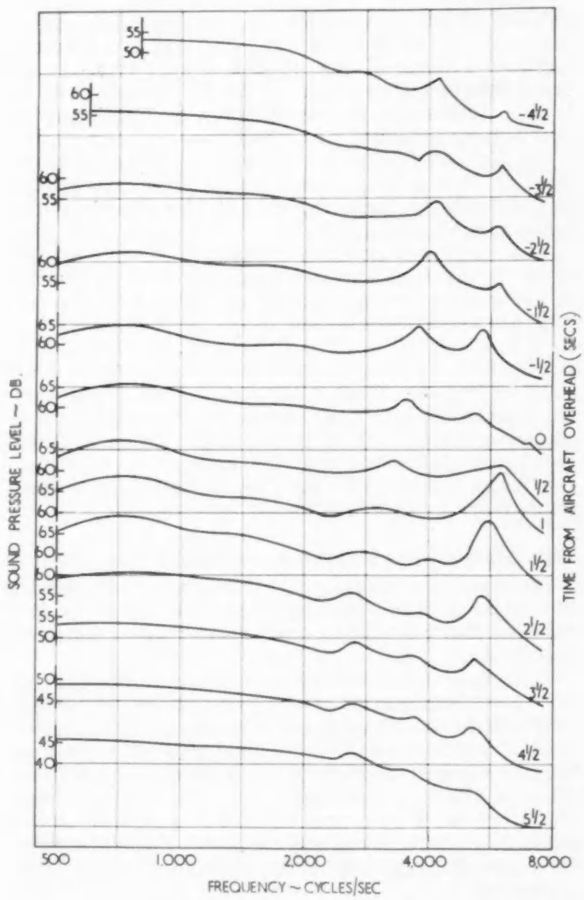


Fig. 3 — Change of spectrum with time.

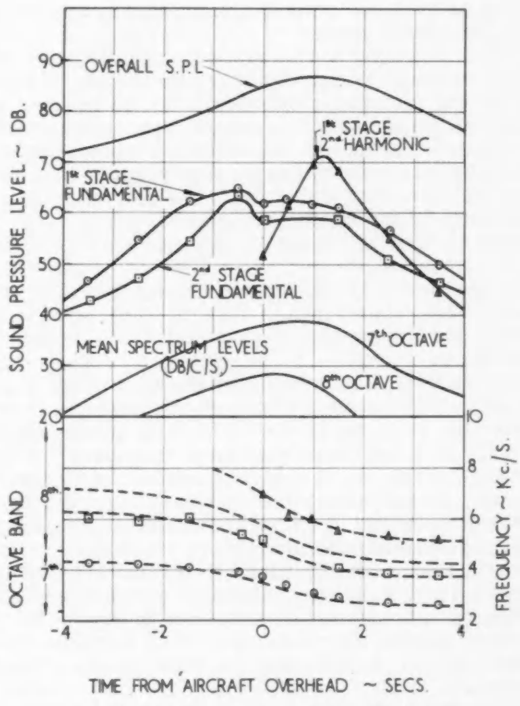


Fig. 4 — Analysis of noise variation with time.

the Doppler effect as the aircraft flies overhead . . . the speed of the aircraft is such that the frequency of the note heard when the aircraft is flying away from the observer is almost down to half that which is heard as it flies toward him.

Fundamental blade passing frequencies of the first, second, and third stages of the compressor have been plotted, and also the second harmonic of the first stage. Points on both graphs are the peak values of noise, and of the frequency at that peak, taken off the previous curves at the various moments of time.

The first stage fundamental can be clearly identified over the whole period of time on the graphs, since the measured frequencies agree very closely with the theoretical ones. Similarly the second stage fundamental can be identified over most of the time scale although there is a gap around ½–1 sec after the aircraft has passed overhead, during which it is not possible to identify it. There is a faint trace of the third stage fundamental but the graphs are not reliable enough to show it at all accurately. On the other hand, there is very clear evidence of the first stage second harmonic rising very rapidly to a peak just after 1 sec after overhead, and falling again very rapidly — also very clearly identifiable by the frequency peaks agreeing very closely with the theoretical.

It is possible that there is also some second stage second harmonic present, but the frequencies of this component would be beyond the range of the equipment used during these tests, and in fact would be above or near the limit of the audible range during most of the fly-over.

When listening to this noise it is particularly difficult to grasp exactly what one is hearing because of the big variation of frequency due to the Doppler effect as the aircraft flies past, but this graph makes it rather clearer. As the aircraft approaches, the overall white noise builds up slowly, rising to a peak around 1 sec after the aircraft has passed overhead, and then falling again quite slowly.

Also plotted are the mean spectrum levels of this white noise as db per cycle for the seventh and eighth octaves which contain the discrete frequencies. The corresponding octave levels are 34 db higher for the seventh octave and 37 db higher for the eighth octave.

Considering the seventh octave at a point about ½ sec before the aircraft passes overhead the octave level has reached 71 db. The first stage fundamental has been rising rapidly to a peak at this moment of 65 db, and it is therefore contributing slightly to the total noise in this octave and is, of course, 'coloring' it very distinctively. This first stage fundamental then falls off slightly. But around 1 sec after overhead it is reinforced by the second stage fundamental which has dropped sufficiently in frequency by this time to appear in the seventh octave, although they are both some 10 db down on the white noise in that octave at that moment.

Considering now the noise in the eighth octave, at about ½ sec before overhead, the white noise is at a level of 64 db. The second-stage fundamental actually reaches the same level at this point before it falls off again, to be succeeded by the very rapid rise in the first stage second harmonic. This reaches a peak of 71 db at 1.2 sec after overhead, some 9 db above the level of the white noise at that moment. The double peak shown in the original traces of Fig. 2 is clearly first a peak of the second stage fundamental and then a peak of first stage second harmonic.

Directivity

The fact that this white noise and these discrete frequency noises rise and fall at different rates, and peak at different times, suggests that they have quite different directivities. Part of this effect is, however, due to the rapid variation of atmospheric attenuation with frequency at high frequencies.

Measurements on an engine running statically on the ground at these approach rpm show that it is the noise in front of the compressor, within ± 30 deg of the engine axis, which is the loudest, both for the white noise and for the discrete frequencies; but as the aircraft flies overhead this noise has to traverse a long path before it reaches the observer on the ground and suffers considerable attenuation.

It is therefore very difficult to correlate reliably the noise heard in front of the compressor from an aircraft flying overhead with that from an engine running on the ground. However, it is the noise radiated around 90 deg to the engine axis (to be exact between 60 deg and 120 deg to the axis) which is most important to the observer, and this gives a much more satisfactory correlation.

Fig. 5 shows the octave analysis of the noise measured at 90 deg to the engine axis from one engine in the Canberra while running on the ground at the same rpm as used in flight.

The noise was actually measured for one engine at 100 ft distance and has been corrected to the 500 ft altitude of the flight tests by inverse square law plus an extra attenuation in db per thousand feet of 0, 0, 0, ½, 1½, 4, 7, 12 db respectively in each of the standard 8 octaves, and then increased by 3 db for two engines. This is the full line on the graph; the points are the noise levels at this angle (at ½ sec after overhead) from the flight tests, and are the mean of four runs of the aircraft at this rpm. Both the noise level and the variation with frequency are in extremely good agreement.

Calculation in terms of compressor characteristics

It seems, therefore, that there is no mysterious difference between the approach noise from the aircraft in flight and that from an engine running on the ground.

Therefore this noise can be accounted for in terms of the characteristics of the compressor concerned.

White noise — This could be produced by the shedding of vortices from the blades; and must then be largely a function of the work done on the air in its passage through the blade row. The noise should therefore be a function of $M \Delta T$ where M is the mass flow through the engine and ΔT the temperature rise through the stage of blades under consideration.

For this white noise we need only consider the

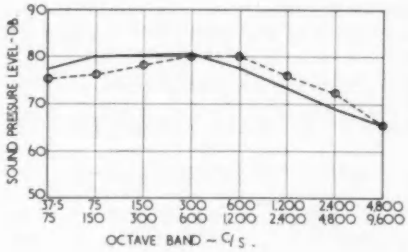


Fig. 5 — Comparison of flight (points on graph) and ground (full line) test spectra.

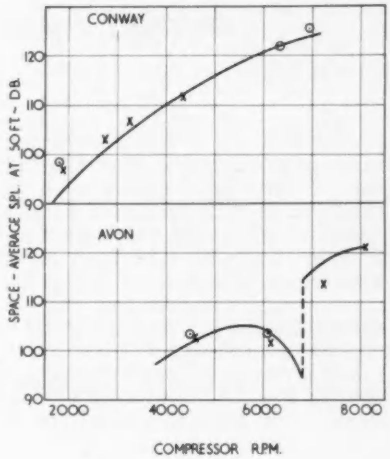


Fig. 6 — Comparison of measured and estimated compressor noise — white noise.

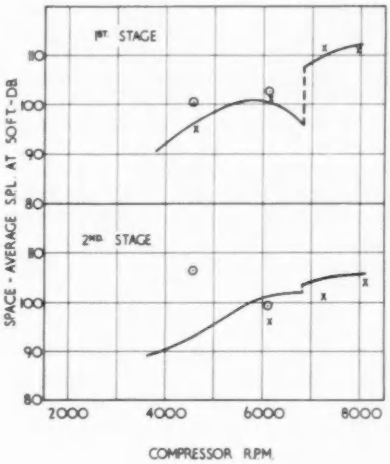


Fig. 7 — Comparison of discrete frequency components of measured and estimated compressor noise — Avon engine.

first stage of the compressor, since the white noise produced by one jet at any rate will completely shield that produced by another behind it, and something of the same sort of mechanism may well be taking place here. There is a formula derived from measurements on ventilating fans which can be expressed as:

Space average sound pressure level (SPL)

$$\propto (M \Delta T)^{1.5} \times \left(\frac{M \Delta T}{B}\right) 0.27$$

where B is the number of blades.

This expression has been used to predict the space average white noise for certain Avon and Conway engines at a distance of 50 ft away over a range of rpm. Results are shown as the lines in Fig. 6.

The formula has been used to give the variation of noise only. The absolute level has been arbitrarily fixed to agree with the 8100 rpm point for the Avon (the dotted part of the Avon line is the operating range of rpm of the bleed valves which are open at low rpm and closed at high rpm). The different sets of points shown for the Avon are measurements made on an engine on two different occasions, while those for the Conway are measurements made on two different engines. The calculation of the space average SPL over the hemisphere round the front of the engine has been carried out for only a few rpm although the results are available at very many different rpm's.

The formula predicts the variation of noise of the Avon extremely well; the same formula (with its constants chosen for the Avon) evidently predicts the Conway noise very closely also, both its variation and its level agreeing well with the measured points, although there are signs of departure from the predicted line at the bottom end of the rpm range. The excellent agreement with the Avon results, in spite of a very discontinuous variation with rpm, is sufficient to discount any suggestion that the noise might be combustion noise, rather than compressor noise.

Discrete frequency components — For discrete frequency noise an analogy is drawn with propeller noise as calculated for the dipole noise due to the lift of the blades. It can be reduced to the form:

$$\text{Space average SPL} \propto \frac{M^2 \eta \Delta T}{D^2(1 - r^2)^2}$$

where η is the stage efficiency, D the tip diameter, and r the hub/tip ratio. In this formula the Bessel function term in the original expression is replaced by a constant. This means that we are left with no way of distinguishing between the levels of the various harmonics of the noise. As a first step, therefore it was examined how this formula predicts the variation of fundamental frequency noise from the compressor.

Fig. 7 shows predicted variation in space average SPL for the first and second stages of the Avon compressor. The constants are chosen to agree reasonably well at the top end of the rpm scale for the first stage. For the second stage an arbitrary reduction of 5 db has been applied over the whole rpm range. Measured points on Figure 7 have been extracted at the appropriate frequency. Prediction of the first-stage noise is very good, but that of the second stage is poor at low rpm. A similar comparison has been made in Fig. 8 for the first and second stages of the Conway (the calculations being made using the constants chosen for the Avon). Again it can be seen that both the level and the variation of the noise for the first stage is predicted quite well, and again that of the second stage is reasonable except at the low rpm end.

These two attempts to correlate the approach noise of Rolls-Royce bypass engines with their compressor characteristics are so far quite encouraging. These are the only two sources of noise which are significant in the engines, but it seems likely that

Aircraft Approach Noise

. . . continued

there is at least one other type of noise which can occur. This can be described as a "siren" noise, produced by the pressure field round each compressor blade being driven past an obstacle such as a stator blade at very high rotational tip speeds. This would of course be a discrete frequency noise at the same frequency as the lift noise described above, and would be expected to rise particularly rapidly in intensity at high rpm's.

The Avon and Conway results show no evidence of this type of noise, and Rolls-Royce hasn't observed it on any other axial-compressor engines.

This "siren" noise may, however, be important in the case of the adaptation of an existing engine to make it into a bypass engine, where it may not be possible to avoid very high rotational tip speeds, even though the blade loadings can be kept quite normal by using a sufficient number of stages.

Possible methods of reduction

The only clue offered by the formulas seems to be that to reduce the noise it is necessary to reduce the blade loading (i.e. the stage temperature rise).

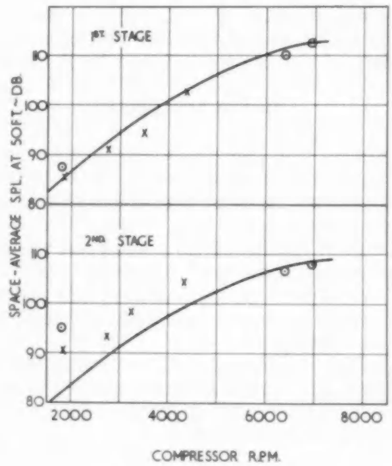


Fig. 8 — Comparison of discrete frequency components of measured and estimated compressor noise — Conway engine.

To do this in the basic design of the engine means increasing the number of stages in the compressor so that as usual a compromise is involved, in this case between the conflicting requirements of lower noise and light weight.

It may be possible to achieve some reduction of noise by lining the inlet duct with acoustic lagging, at the expense of weight and increased specific fuel consumption.

Another method is to adjust the area of the inlet so that the air reaches sonic velocity at a throat through which the noise is not able to travel forward (except of course in the boundary layer). Unfortunately, this poses a severe mechanical problem, because this throat must have an area only around ⅓ of that which is normally used. Inlet losses corresponding to this small area at normal take-off and cruising thrusts would obviously be so prohibitive that any mechanism must be designed to be absolutely fool-proof in its fail safe characteristics.

However, there is no doubt that such a device undoubtedly has an enormous effect on the noise coming out of the front of the engine. Fig. 9 shows the variation in overall sound pressure level at a point 50 ft in front of the intake at 10 deg off the engine axis for an Avon engine. The upper curve shows how noise varies with rpm over the whole rpm range when fitted with a normal inlet. The lower curve shows the corresponding figures when fitted with an inlet with a central bullet designed to choke at 4,500 rpm. There is about 28 db reduction noise under these conditions.

The upper graph of Fig. 10 shows the ⅓ octave analysis of the noise at this point in the two cases. There is a reduction of as much as 20 db in the white noise, and nearly 40 db in the discrete frequency components.

Unfortunately this spectacular reduction in noise is not achieved at 90 deg to the engine axis, as the lower graph of Fig. 10 shows. At this point there is no significant reduction in the white noise, and, of course, the flight tests have shown that it is the noise transmitted in this direction which is important. There is around 10 db reduction in the discrete frequency components which would probably be very valuable.

To Order Paper No. 162C . . .
from which material for this article was drawn, see p. 6.

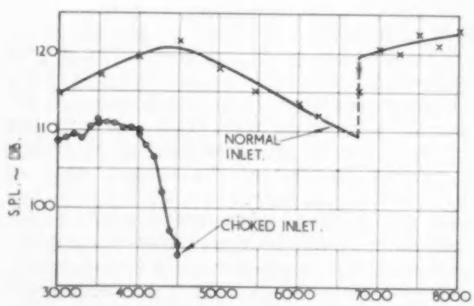


Fig. 9 — Effect of choked intake on compressor noise.

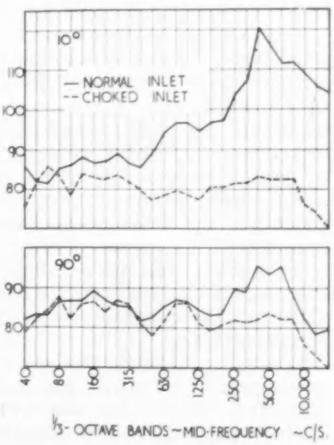
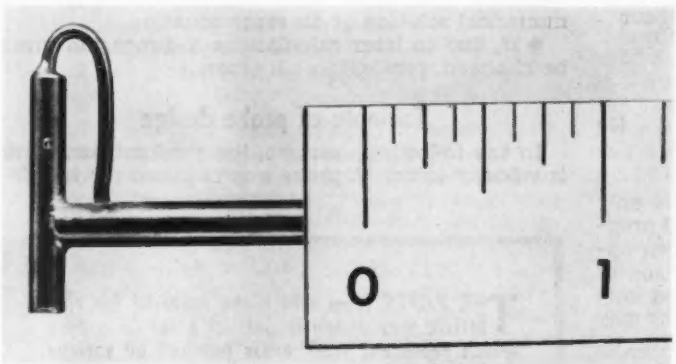
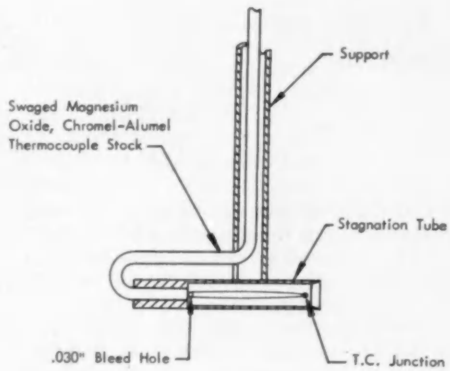


Fig. 10 — Effect of choked intake on noise spectrum.

Thermocouple probe design method . . .

. . . provides suitable environment for measuring gas temperatures. Stagnation tube reduces velocity error.





Total temperature stagnation probe.

NOMENCLATURE

c_p	Specific heat at constant pressure, Btu/lb
d_w	Diameter, thermocouple wire, in.
g	Gravitational constant, ft/sec^2
h	Convective heat transfer coefficient, Btu/hr ft^2 F
J	Conversion factor, Btu to ft-lb, ft-lb/Btu
k_m	Thermal conductivity, metal, Btu/hr ft^2 F ft
L	Thermocouple junction length, in.
M_n	Mach number
T_e	Effective temperature, R
T_j	Junction temperature, R
T_t	Total temperature, R
T_w	Wall temperature, R
V	Velocity, fps
α	Recovery factor
γ	Specific heat ratio (constant pressure to constant volume)
ε	Emissivity
σ	Stephen-Boltzman constant $.174(10)^{-8}$ Btu/hr ft^2 R^4

Based on paper by

Laurence B. Haig

Research Laboratories, General Motors Corp.

THERMOCOUPLE PROBES can be designed to measure gas temperatures accurately under steady-state conditions by reducing the effect of the gross environment. This is accomplished by surrounding the thermocouple with an envelope which provides a more favorable local environment within it.

Total error in temperature measurement can be divided into velocity error, radiation error, and conduction error. An example of probe design procedure in which the predominant error is velocity error is given below. This procedure consists of the following steps:

1. Ascertain the maximum allowable temperature measurement error.
2. Determine the approximate gross environmental conditions.
3. Compute the total error and error distribution of a bare wire thermocouple under the gross environmental conditions.
4. Determine the local environment necessary to reduce the total error to the specified limits. All

Thermocouple probe design method

. . . continued

three forms of error must be investigated for the proposed environment of the junction.

5. Select an envelope which will provide the desired internal velocity, radiation, and conduction conditions.

6. Calculate the errors resulting from the prescribed local environment and compare them to the accuracy requirements. If total error is not acceptable, repeat steps 5 and 6. However, caution must be exercised when an environment change is made, since an increase in conduction and radiation errors will usually accompany a reduction in velocity error or vice versa.

Equations and variables available to designer

Velocity error

$$T_t - T_e = \frac{(1-\alpha)\frac{\gamma-1}{2}(M_n^2)T_t}{1+\frac{\gamma-1}{2}(M_n^2)} = \frac{(1-\alpha)V^2}{2gJC_p} \qquad (1)$$

Considering the equation on the right, the only variable in the denominator is a working fluid property and therefore cannot be altered in a given application. The recovery factor, α, is a function of the thermocouple geometry and can be varied only between narrow limits. Thus, only the velocity may be altered to effect a reduction in velocity error.

Conduction error

$$T_e - T_j = \frac{T_e - T_w}{\cosh\left(L\sqrt{\frac{4h}{k_m d_w}}\right)} \qquad (2)$$

This equation is a form of the fin equation. Numerous studies show that the loop junction thermocouple performs according to this equation provided that the thermocouple is treated as a compound fin. That is, the support structure must be treated as one fin and the loop junction as a second fin in series with the first. Therefore, the designer may confidently use equation (2), with the limitation, to bring conduction error within acceptable limits.

The concept of effective gas temperature, T_e, is important to the determination of both conduction and radiation errors. Effective gas temperature, T_e, is defined as the maximum temperature the junction can attain with no heat losses due to either conduction or radiation. Thus, effective gas temperature is equal to the total gas stream temperature minus the velocity error of the thermocouple junction. In other words, velocity error must be known in order to determine conduction or radiation error.

In the case of conduction error, only h, the convective heat transfer coefficient, and $(T_e - T_w)$, the wall temperature depression, are determined by gas stream conditions. Consequently, the designer has the immersion length, L, the diameter, d, and the thermal conductivity, k, available to aid in the reduction of conduction error. Of these three, the immersion length is the most important since its effect is an order higher than either diameter or thermal conductivity.

Radiation error

$$T_e - T_j = \frac{\sigma\varepsilon}{h}(T_j^4 - T_w^4) \qquad (3)$$

Radiation error is obviously controllable only by controlling the wall temperature, T_w, as all other variables in the equation are determined by gas stream properties.

Precautions — When following the general procedure outlined above, the calculations will be most fruitful if the following precautions are observed:

- Error calculations must be made at the maximum and minimum conditions of temperature, mass velocity, and Mach number. At least one intermediate flow condition should also be investigated.
- Assign no dimensions to the thermocouple or its envelope until that dimension is required for a numerical solution of an error equation.
- If, due to later calculations a dimension must be changed, recalculate all errors.

Example of probe design

In the following example, the predominant error is velocity error. A probe was required for the de-

THE PAPER from which the material for this article was drawn is part of a set of papers which represent work areas pursued by various technical subcommittees of SAE Committee AE-2 Physical Measurement Sensing. To order them, see p. 6 These papers are:

Basic Studies on Base-Metal Thermocouples, by J. F. Potts, Jr. and D. L. McElroy (Paper No. **158A**)

Materials for High (2500-4000 F) Gas Engine Temperature Measurements, by A. R. Anderson and D. J. MacKenzie (Paper No. **158B**)

A Design Procedure for Thermocouple Probes, by L. A. Haig (Paper No. **158C**)

Experimental Determination of Thermocouple Time Constants with Use of a Variable Turbulence, Variable Density Wind Tunnel, and the Analytic Evaluation of Conduction, Radiation, and Other Secondary Effects, by A. F. Wormser (Paper No. **158D**)

A Stable High Temperature Thermometry Rig, by R. J. Moffat (Paper No. **158E**)

Intercomparison of Thermocouple Response Data, by F. R. Caldwell, L. O. Olsen, and P. D. Freeze (Paper No. **158F**)

Dynamic Testing of Gas Sampling Thermocouples, by J. D. Meador (Paper No. **158G**)

Time Response Characteristics of Temperature Sensors, by M. D. Scadron (Paper No. **158H**)

termination of the efficiency of a single stage of an axial flow gas turbine compressor. This application immediately established the environmental conditions of the probe and the required measurement accuracy.

Accuracy Requirement — The maximum allowable error for the probe was set at 0.2 F after reviewing the associated instrumentation, the uniformity and stability of the air stream, and the accuracy required for the compressor study. Further reduction of the temperature measurement error would not increase the overall accuracy of the efficiency determination because of the error limits of the other measurements.

Gross Environmental Conditions. The following statement of operating conditions was obtained from the project engineer:

a. Gas stream temperature level:	75–100 F
b. Mach number range:	0.2–1.0
c. Mass velocity range:	17–92 lb/ft^2 sec
d. No attempt to deliberately heat or cool test facility walls.	
e. Estimated temperature rise across stage:	20 F

Temperature and mass velocity increase with Mach number in this application.

Total Error and Error Distribution for Bare Wire Thermocouples — Assume the following bare wire thermocouple: 0.125-in. diameter, swaged constructions, magnesium oxide insulated, chromel-alumel thermocouple stock. Junction length, 0.250 in.; wire diameter, 0.022 in.; support immersion, 2.0 in. Thermocouple will be installed with the junction wires parallel to the flow and the junction bead upstream.

Applying the above test conditions to equation (1), the velocity error for a bare wire thermocouple is determined to be 14 F at Mach 1.0 and 0.67 F at Mach 0.2. The recovery factor, α, has been determined experimentally, and for cylinders parallel to the flow stream, is 0.85 and independent of wire size and length.

Conduction error, as described by equation (2), cannot be determined unless the approximate difference between the effective temperature and the wall temperature is known. Assuming the wall temperature to the average of the gas stream total and gas stream static temperatures, equation 1 yields wall temperature depressions of about 33 F at Mach 1.0 and 2 F at Mach 0.2. Equation 2 may now be solved for conduction error which is approximately 0.31 F at Mach 1 and 0.1 F at Mach 0.2.

Radiation error must also be approximated since it is a function of wall temperature. Solving equation (3) yields radiation errors of approximately 0.03 F at Mach 1 and 0.005 F at Mach 0.2.

The calculated total bare wire thermocouple error is, therefore, distributed as follows:

Free Stream Mach Number	0.2	1.0
Velocity	0.67 F	14.0 F
Conduction — approximately	0.1	0.31
Radiation — approximately	0.005	0.03
Total error	0.78 F	14.34 F

Local Environment Selection — From the preceding summary, in order to decrease the velocity error (the most significant factor) the velocity in the region of the thermocouple junction must be reduced. The maximum allowable local velocity can be calculated from the allowable velocity error (equation 1).

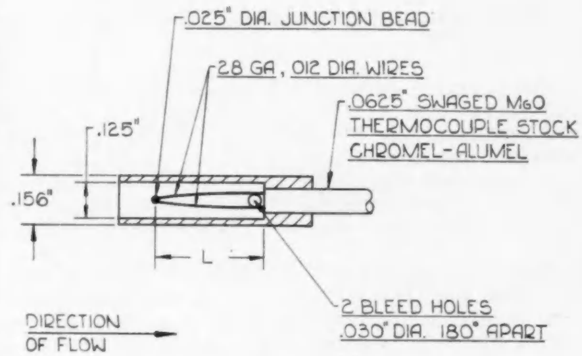


Fig. 1 — Modified stagnation tube.

As a preliminary estimate, the desired total error of 0.2 F was distributed among the three error forms as follows: Velocity error 0.10 F, radiation error 0.09 F, and conduction error 0.01 F.

For a velocity error of 0.10 F the maximum allowable Mach number is 0.0772. At this low Mach number the problems of radiation and conduction error may be increased greatly. The magnitude of these errors can only be calculated when the dimensions of the envelope are selected.

Envelope Selection — Selection of suitable envelope to provide the proper local environment is determined by the most significant error. Normally the designer would rely on past experience for the preliminary envelope design. However, a literature search of special purpose temperature probes will sometimes suggest a suitable envelope.

In the example shown here a stagnation tube was selected on the basis of previous work done on the reduction of velocity error.

The principal function of the envelope chosen for this example is to reduce the local Mach number from 1.0 to 0.0772. The gas may be brought entirely to rest with a stagnation tube.

However, at zero velocity, the temperatures of the junction will be equal to the temperature of the stagnation tube due to conduction and radiation. Since the stagnation tube is located in the same gross environment as the previously evaluated bare wire thermocouple, it is subject to the same temperature depression.

To resolve this problem a small exit or bleed hole may be provided to allow some gas to flow through the stagnation tube thereby continually replacing the stagnated air surrounding the junction.

The bleed hole must be sized so that the internal Mach number does not exceed the limit of 0.0772. To determine the size of the bleed holes, it was assumed that the internal static pressure was equal to the free stream total pressure and that the bleed hole discharged to free stream static pressure. It was further assumed that no loss coefficients need be applied to the bleed holes.

Required entrance hole to bleed hole area ratio was determined from the gas tables to be 8.01 to 1. The stagnation tube, as modified, is shown in Fig. 1. Note that two bleed holes are located at the base of the stagnation tube thereby exposing all of the

Thermocouple probe design method

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bared junction wires of the moving gas stream to aid in the reduction of conducting error.

Stagnation tube dimensions compatible with the design requirements are also shown in Fig. 1.

Error Calculation Based on Local Environment — Velocity error has been reduced by the design of the stagnation tube and bleed holes to 0.10 F maximum.

Radiation error is now calculated in terms of heat transfer from the junction to the stagnation tube. The stagnation tube, which is also a cylinder parallel to the flow, remains 14 F cooler than the total temperature of the gas at Mach 1. The low mass velocity inside the stagnation tube usually causes a relatively high sensitivity to radiation error, especially at higher temperature levels.

For the envelope shown in Fig. 1, the radiation error is 0.0747 F at a free stream Mach number of 1.0 and 0.0060 F at a free stream Mach number of 0.2. This is within the allowable radiation error limits.

It is unusual, however, that radiation error is largest at the high velocity end of the flow range. Generally, radiation and conduction errors are most severe at the low velocities.

The anomalous behavior of this probe design exists because the temperature of the sink which the junction "sees" (stagnation tube wall) decreases proportionally to the square of the free stream velocity while the heat transfer from the gas to the junction increases approximately in proportion to the square root of the internal velocity.

Conduction error is calculated for both maximum and minimum flow conditions. The stagnation tube acts as a sink for the conduction of heat from the thermocouple junction. Again, the temperature depression is largest at a free stream Mach number of 1.0. By using a junction 0.6 in. long, it is possible to reduce the conduction error to .01 F or less over the entire flow spectrum. This length includes a safety factor over the design length.

The total calculated error distribution of the proposed probe design is as follows:

Free stream Mach number	0.2	1.0
Velocity error	.0075 F	0.1000 F
Radiation error	.0060 F	0.0747 F
Conduction error	.01 F	0.01 F
TOTAL ERROR	0.0235 F	0.1847 F

The total error is within the required accuracy at both extremes of the flow range.

Further improvements can often be made on a probe design that are not included in the general design procedure. In this instance two such refinements were incorporated. First, the inlet to the stagnation tube was beveled at a 60 deg included angle to decrease the sensitivity to pitch and yaw angle. Second, due to a loss of heat from the gas to the stagnation tube, the gas temperature will decrease as it passes from the stagnation tube entrance to the bleed holes. In order to sense the correct gas temperature, the thermocouple junction was located at the entrance to the stagnation tube.

To Order Paper No. 158C . . .
from which material for this article was drawn, see p. 6.

Thermoelectric Module

Air conditioning unit could be used for sealed cabin for durations up to approximately 100 days

Based on paper by

Herman L. Hall and Paul L. Catron
Douglas Aircraft Co.

FEASIBILITY OF A THERMOELECTRIC COOLER incorporated in a sealed cabin cooling system (Fig. 1) has been demonstrated by Douglas Aircraft.

Their working model combines a Peltier cooler with a potassium superoxide (KO_2) bed (the latter absorbs carbon dioxide and replenishes oxygen). Such an arrangement is shown in Fig. 2 and the feasibility model at the top of the page. The model was sized to house two mice in the cabin. The cooler was designed to the modular concept.

It can be seen from Fig. 2 that a limited-duration closed environment air conditioning system can be had with only one moving part—a fan for circulating air. It has the advantages of mechanical simplicity, long life, quiet operation, lack of contaminating fluids, and inherent reliability. Applications include spacecraft and nuclear subs.

Design

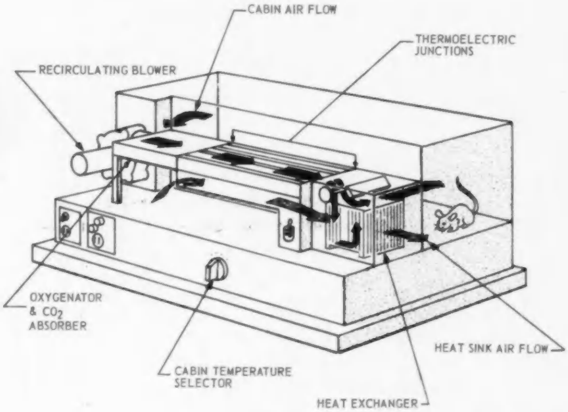
The thermoelectric cooler for the feasibility model was designed with three modules forming the complete thermoelectric cooler for the model.

Modular construction was chosen because modules may be used as "building blocks" to put together almost any size cooler; and from the production viewpoint make an attractive design because the components for a cooler or coolers are all alike. Trouble shooting and repair are simplified because a defective module can be replaced to restore an entire cooler to operating condition again, much like replacing a defective light bulb on a series string of Christmas tree lights.

Since a thermoelectric cooler is inherently a high-amperage low-voltage device, the junctions will usually be connected electrically in series in order to keep the current to a minimum. This in turn reduces the size and weight of wires, switches, and other electrical equipment.

Commercially available bismuth telluride thermo-

Air Conditioning Is Feasible



FEASIBILITY MODEL of sealed cabin air conditioning system. Arrows show cabin air flow and heat sink air flow.

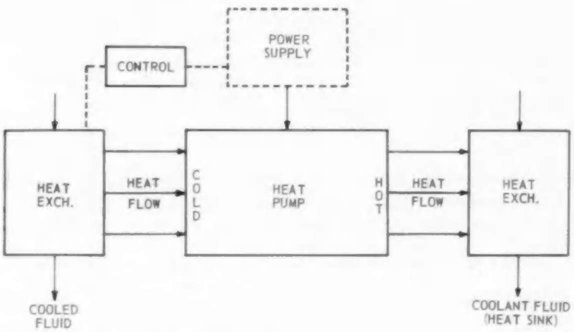


Fig. 1 — Refrigeration system.

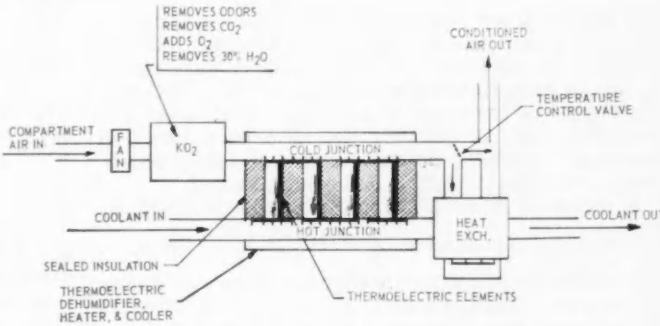


Fig. 2 — Schematic of sealed cabin air conditioning system.

elements were used having the dimensions of ¼ inch diameter × ¼ inch long and a figure of merit $Z = 1.9 \times 10^{-3}$/deg K. By using these available thermoelements the problem of determining the proper dimensional proportions for the thermoelectric elements was side-stepped.

The following equations are useful in calculating the theoretical performance of a Peltier cooler.

$$Q_{in} = SiT_c - (\tfrac{1}{2}\, i^2 R) - (K\Delta T) \quad (1)$$

$$W = Si\Delta T + i^2 R \quad (2)$$

$$Q_{out} = Q_{in} + W \quad (3)$$

$$\text{C.O.P.} = \frac{Q_{in}}{W} \quad (4)$$

where:

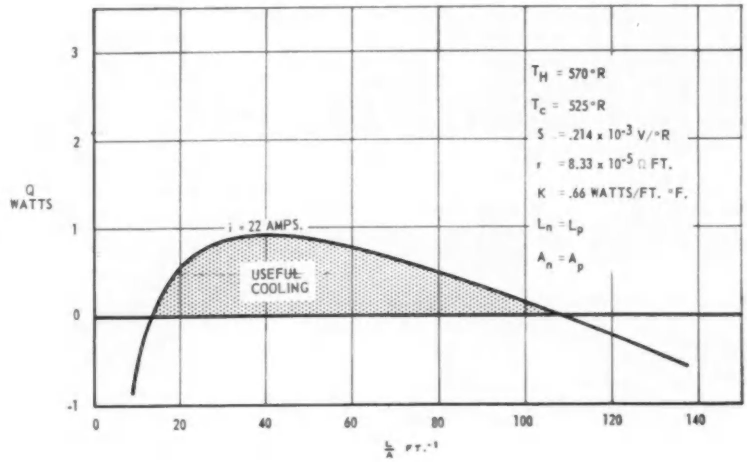
Q_{in} = Cooling capacity (watts)
S = Seebeck coefficient (V/deg K) $[|S_n| + |S_p|$ for a junction$]$
i = Current (amperes)
T_c = Cold junction temperature (deg K)
T_H = Hot junction temperature (deg K)
$\Delta T = T_H - T_c$
$R = \dfrac{rL}{A}$ = Resistance (ohms)
$K = kA/L$ = Thermal conductivity (watts/deg K)
W = Power required
Q_{out} = Heat dissipated
C.O.P. = Coefficient of performance (ratio of cooling capacity to required power)
r = Specific electrical resistivity $[r_n + r_p$ for a junction$]$
k = Specific thermal conductivity $[k_n + k_p$ for a junction$]$
$L = L_n = L_p$ = Length of thermoelement
$A = A_n = A_p$ = Area of thermoelement

Subscripts n and p represent the negative and positive thermoelements respectively.

There are eight variables to consider in a thermoelectric cooler design. In the Peltier cooling equation (Eq. 1), zero junction resistance and zero thermal losses external to the thermoelement are assumed. In actual practice, these two assumptions are not true, so they must also be accounted for when undertaking a particular design problem.

There seems to be no convenient way of optimizing all of these variables. However, as often is the case in a specific design problem, many of these variables

Fig. 3 — Single junction cooling capacity for constant current.



Thermoelectric Air Conditioning Module Is Feasible

. . . continued

will become fixed within a narrow range so that the remaining ones can be more nearly optimized. For instance, if the heat sink being used is water, then T_H would have to be kept below 212 F. If the cooler is going to be used also as a dehumidifier, as in our feasibility model design, then the cold junction temperature would be kept above freezing, somewhere near the dewpoint being maintained.

A choice of materials would probably be made by comparing their figures of merit, $Z = \frac{S^2}{RK}$ (deg K^{-1}). Generally speaking, the higher the figure of merit, the better; if cost, availability, or physical strength is not adversely affected. Once the material has been chosen, then S, r and k are known.

Thus, five of the eight variables in the basic cooling equation have been pretty well determined. The three remaining variables are length, area and current.

When the first five variables are known, Fig. 3 can be drawn, which shows a typical plot of the effect of length to area ratio when current is held constant. Fig. 3 clearly shows the range of $\frac{L}{A}$ ratios which will give useful cooling for the selected current, $i = 22$ amp. It also shows the maximum cooling capacity for such a junction when operated at this assumed current value. There is a specific $\frac{L}{A}$ ratio associated with this maximum cooling point.

Here an interesting observation can be made. Using the length to area ratio associated with the maximum cooling point of the curve for $i = 22$ amp, the current which will give the maximum cooling for this particular $\frac{L}{A}$ ratio can be determined. It will be a higher current. Q_{max} for this $\frac{L}{A}$ ratio can be calculated and the maximum cooling available from a single junction found. By plotting the Q_{max} curve on this graph, the maximum cooling for any $\frac{L}{A}$ ratio will have been defined (Fig. 4). This shows, then, that a single junction can be designed to do any size cooling job if any $\frac{L}{A}$ ratio and current is acceptable, and sufficient heat exchange surface is possible.

Superimposed on this plot is the useful cooling curve for several values of constant current. This shows that Q_{max} for a given current can always be increased (for the variables assumed fixed) by additional current without changing the $\frac{L}{A}$ ratio.

This, then, can give the designer some latitude if he is designing a cooler to operate at Q_{max} for a specific current, in that he can always get some additional cooling capacity from his design if it is required. This, of course, would not be the case if he designed the cooler to operate at Q_{max} for a specific $\frac{L}{A}$ ratio. In most applications a power supply will be a real consideration and will provide the designer with a current limitation, which in turn provides him with maximum for one of the three remaining variables. Operating a cooler at high current levels may tax the power supply capacity or capability and will require large wires and bus bars to handle the large amperage. If AC is to be rectified to DC for power supply, then large amperage rectifier designs and transformer designs become a problem. All of these things must be brought into the system design problem in a real situation and the best overall compromise attempted. Other criteria for choosing the thermoelement proportions that best suit particular design conditions are: the distance heat is to be pumped; expected junction resistance; junction strength, and efficiency of operation.

There are certain installations where economy of operation will be of prime importance, so that the designer will desire a high coefficient of performance (ratio of cooling capacity to power required).

A plot of maximum C.O.P., superimposed upon the

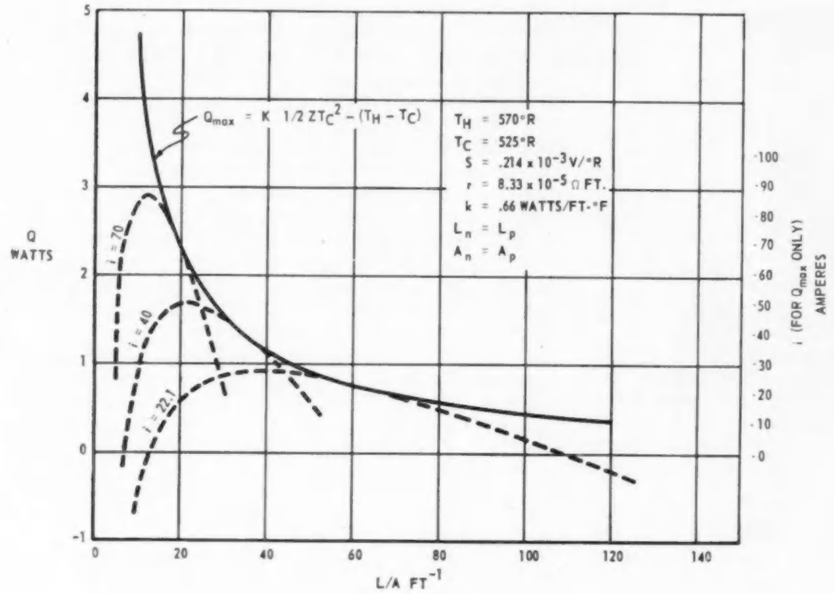


Fig. 4 — Single junction cooling capacity; maximum cooling for any L/A ratio can be defined.

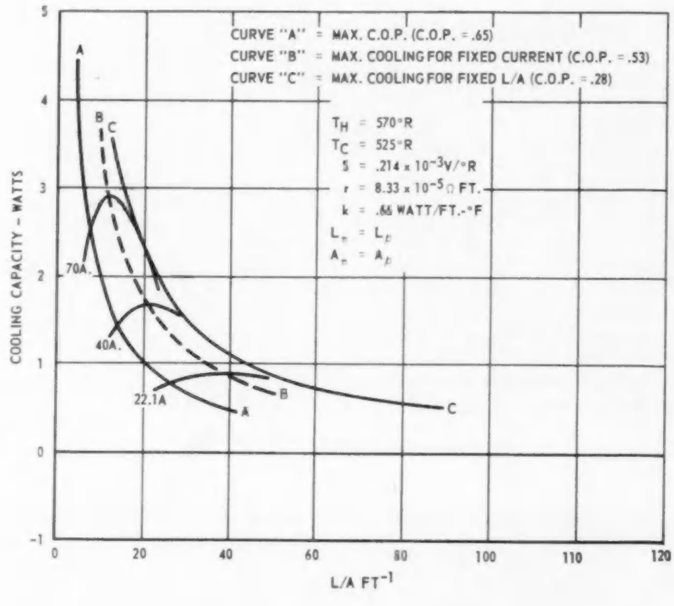


Fig. 5—Single junction performance.

conditions just plotted, is shown in Fig. 5. Curve A would be the line of most economical operation and will give the minimum heat exchanger weight because it represents the minimum heat dissipation due to power loss for the conditions stated. For a given size cooling job it will, however, require more junctions for the same operating current, because the cooling capacity per junction is less than the point of maximum cooling for that current or Q_{max} for that $\frac{L}{A}$ ratio.

By connecting the points of maximum cooling for constant current lines the points of maximum cooling for fixed currents will have been defined as shown in Curve B, Fig. 5. Although the C.O.P. is somewhat less, this line represents the lowest number of junctions for a given cooling job when operating with a fixed current. The number of junctions in a cooling module may also be a consideration from the standpoint of fabrication complexity and quality control.

The weight of a thermoelectric cooler is a great concern for any airborne application. For a given cooling capacity, thermoelectric material, and heat pumping distance (thermoelement length, L; there is not much that can be done about reducing the

Thermoelectric Air Conditioning Module Is Feasible

. . . continued

weight of the heat pump portion of Fig. 1 once it has been decided to use either curve A, B, or C for a design. Fig. 5 shows that these curves are inversely proportional to $\frac{L}{A}$; therefore if the cooling capacity of a junction is doubled, the area will double and thus the total volume or weight of thermoelectric material will double. However, only half as many junctions are required to do a given cooling job and the net weight change is zero. Here is where improved materials would help, by raising the entire curve.

The working model thermoelectric cooler must have the heat exchanger portions of Fig. 1 also, in order to properly absorb the heat from the fluid being cooled at the cold end and dissipate the heat to the heat sink fluid at the hot end. The hot junction heat exchanger must not only dissipate the heat being pumped, but also the heat generated by the electrical power losses in the cooler.

In the case of the feasibility model, the total heat exchanger weight was found to be approximately 86% of the total cooling module weight, with the thermoelements representing 6 – 8% of the total weight, and the balance represented by terminal strips, epoxy, and solder.

These percentages will vary greatly from one set of design conditions to another, depending upon the heat sink fluid, its velocity, and the temperature difference between the fluid and heat exchanger. The point is that in many cases, the heat exchanger portion of a thermoelectric cooler will make up a major portion of the cooling module weight. Therefore, efforts spent in reducing thermoelement weight will not reduce overall weight as fast as efforts expended in careful heat exchanger design and fabrication.

The cooling modules for the feasibility model have a cooling density of approximately 0.12 lb/w. Fig. 6 shows a comparison of cooling capacities versus lb/w of cooling of typical airborne vapor cycle refrigeration units with thermoelectric cooling units. The power supply and control system is not included for either method. The vapor cycle data plotted is for random conditions and cooling loads, and represents a highly developed state-of-the-art. The thermoelectric band is based upon Douglas data and estimates and is an infant state-of-the-art system. Nevertheless, it would appear to compete profitably on a weight basis today with vapor cycle units for cooling jobs of approximately 500 w or less. Improvements in materials will lower the thermoelectric line to include ever-increasing cooling loads.

In addition, for certain cooling requirements, thermoelectric cooling has the following special features: No moving machinery, no contamination from refrigerants, silent operation, apparent high reliability, flexibility of design (capacity and shape), small size does not reduce efficiency, and apparent long life.

Applications

This system, scaled up to handle the oxygen, carbon dioxide, cooling, and humidity requirements of one man, could be a portable module. It would consist of a thermoelectric cooler and re-heat section, cabin air blower, replaceable KO_2 canister, and ports for circulating the heat sink fluid. This modular package would be approximately 6 in. × 6 in. × 20 in. and would weigh 20 lb for a 24 hr oxygen supply and 160-w cooling capacity. Reserve KO_2 canisters would replace the exhausted canister for additional 24-hr intervals.

Such a "universal" air conditioning unit may be feasible for a space ship, satellite, submarine, or any sealed cabin for durations up to approximately 100 days.

One such air conditioning module would be used for each crew member. For heat loads imposed by other equipment in the cabin, such as electronic gear, additional modules without the KO_2 canister would be used to achieve the desired cooling capacity.

To Order Paper No. 159B . . .
from which material for this article was drawn, see p. 6.

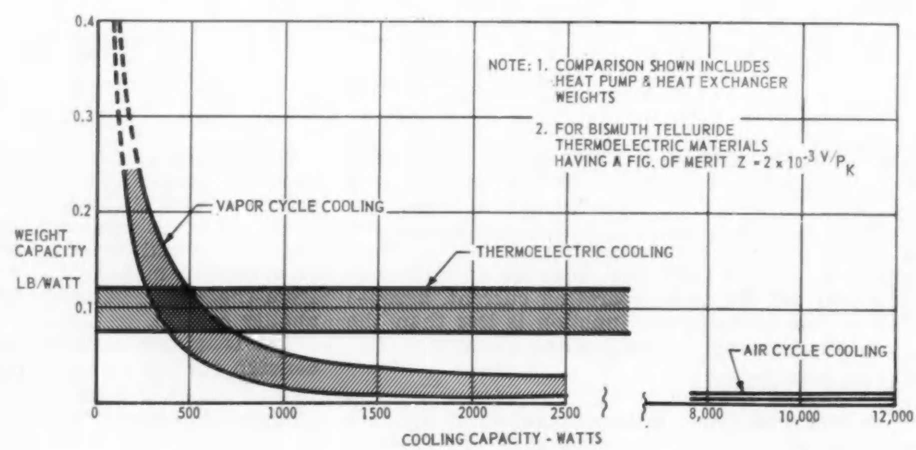


Fig. 6 — Weight of thermoelectric cooling unit compared with typical airborne vapor cycle refrigeration unit.

Cascade Reverser and Daisy Ejector Noise Suppressor Used with CJ805-3 Engine

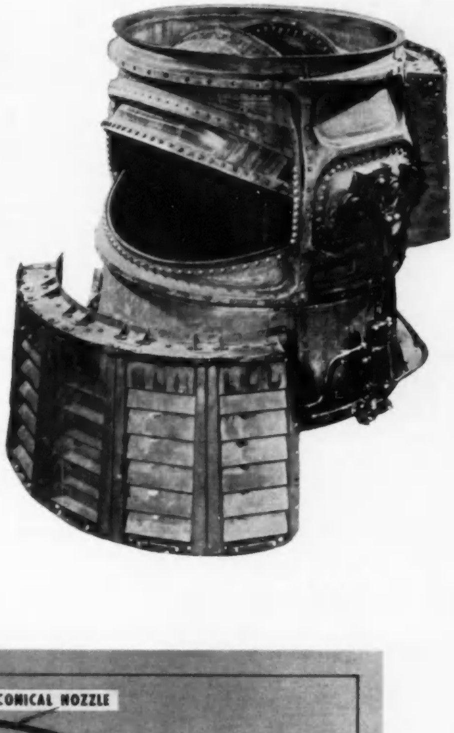


Fig. 1 — CJ805-3 thrust reverser assembly.

Based on paper by

W. S. BERTAUX

Jet Engine Department, General Electric Co.

A CASCADE-TYPE REVERSER and a suppressor which is a daisy nozzle with ejector shroud were selected as good designs for the CJ805-3 engine in the Convair 880 aircraft application.

The reverser was designed to fail safe in that it would not change position (forward or reverse) due to any failure in the unit. The suppressor was selected to reduce jet noise so that it would not be greater than present-day piston engines, and to keep thrust loss to a minimum.

Thrust reverser

The reverser is composed of the major parts shown in Fig. 1. Main body is basically a cone with cutouts extending about 120 deg on each side which allow the exhaust gas to exit from the cone in the reverse thrust position.

There are two blocker doors, pivoted on bearing supports which are mounted on the top and bottom of the cone. These doors serve a dual function. . . . In the forward thrust position they cover the cutout ports in the cone. In the reverse position they rotate aft and block the exhaust pipe, forcing the gases to discharge through the cascades.

A significant feature of the blocker doors is that they are designed to act as a membrane. If there is zero bending moment in the blocker, both the overall stress level and the deflection of the door under load are held to a minimum. Low stresses increase durability, and the absence of deflection aids in arriving at a good seal configuration. The membrane shape is approximated by a basic inside sheet with hat sections of varying cross-section added to the outside.

The actuating mechanism incorporates a linkage which, in the forward thrust position, is past center or in a toggled position. In this position the mechanism is irreversible, and provides one of the basic fail-safe features of the design.

Cascades are contained in assemblies — one on each side of the cone —

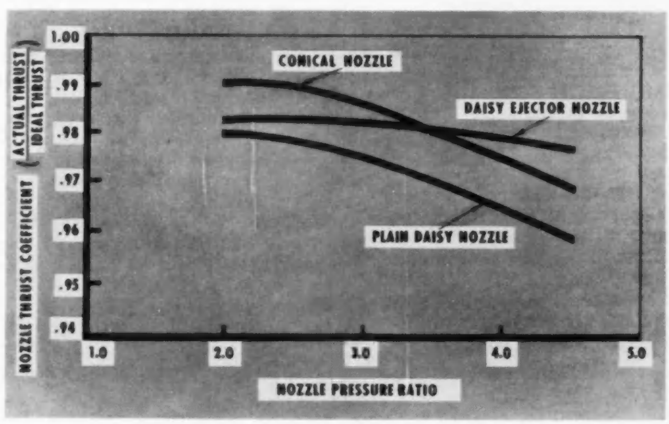


Fig. 2 — Noise suppressor performance.

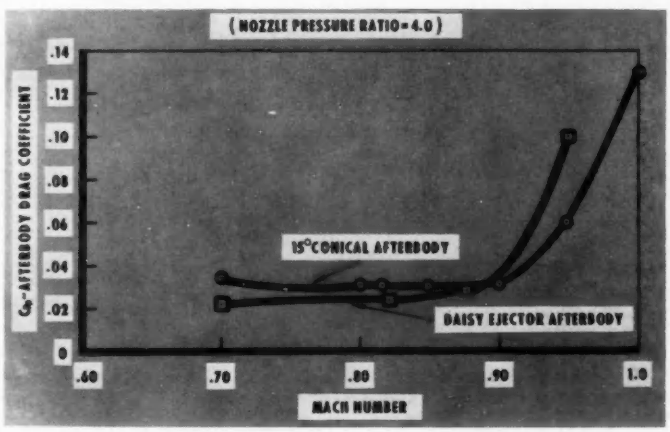


Fig. 3 — Aerodynamic drag of daisy ejector nozzle.

CJ805-3 Engine

. . . continued

each with five boxes or rows of vanes of airfoil cross-section supported from axial beams.

Noise suppressor

Tests comparing noise reduction and performance loss of various suppressor configurations showed that the daisy or corrugated nozzle with eight lobes and a centerbody plug was preferable.

An ejector shroud was added to improve performance of the aircraft-engine combination . . . particularly at the higher pressure ratios where the shrouded nozzle acts similar to a convergent-divergent nozzle.

Composite results of scale model and full scale performance tests are shown in Fig. 2. For comparison, curves are also included for a convergent nozzle and a daisy nozzle without shroud.

That the ejector reduces performance due to the daisy shape is particularly noticeable at pressure ratios above 3.6 where it exceeds performance available from a convergent nozzle. At pressure ratios corresponding to take-off it is slightly lower than the convergent nozzle.

Scale model tests (1/5) indicated that for performance and pumping of the nozzle, shroud lengths between 1½ and 3 in. provided the desired characteristics. But in testing the full-scale shroud some startling results were observed. The 1½-in. shroud met the objectives of noise reduction. . . . However, as the length of shroud was increased, the noise reduction capability of the suppressor was severely compromised.

Drag tests on a 1/7 scale model of the daisy suppressor show that its overall drag coefficient is equal to or less than the drag of a 15-deg conical afterbody up to Mach 0.89 (Fig. 3). Above this, it is somewhat greater.

To Order Paper No. 162B . . . from which material for this article was drawn, see p. 6.

New Electrical System For Earthmover Diesels

Based on paper by

W. C. EDMUNDSON

Delco-Remy Division, GMC

(Presented before SAE Central Illinois Section)

A STRAIGHT 12-v electrical system with a high output 12-v motor for cranking large diesel engines is worthy of attention. It has certain advantages over the three systems using a 24-v motor employed heretofore.

For quite a size range of engines, this 12-v motor will give the comparative results shown in Fig. 1, when the same number and same size of batteries is used with it as with the 24-v motor. The small difference in favor of the 24-v motor will probably be made up for by the better average state of battery charge obtainable in the less complicated charging or load circuits.

The cranking current will be twice as high in the 12-v motor, but the motor has been designed to handle it, with four parallel circuits and new high copper-content brushes. Brush life is actually improved. The solenoid switch contacts give better service because the high current is easier to handle than the severe arcing voltage on 24 v.

To order Paper No. S243 . . . from which material for this article was drawn, see p. 6.

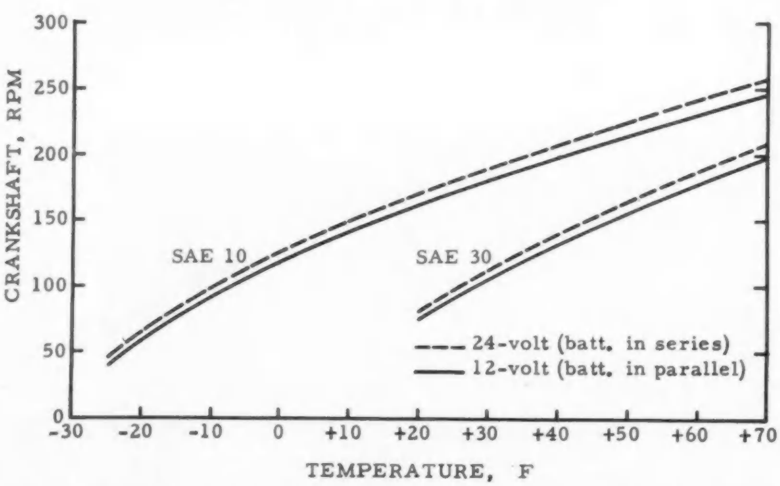


Fig. 1 — 12-v motor cannot quite match the performance of the 24-v motor system in cranking a 750-cu in. diesel, but there are offsetting advantages, such as a better average state of battery charge and longer brush life.

Manufacturing Research New Management Art

Based on report by secretary

F. H. WILLIAMS

General Motors Corp.

THE objectives of manufacturing research may be to develop new or revised designs, work out better processes, or devise new processes which will serve as a bridge to make future production posible. Because objectives vary as well as size of organizations, no one type of research organization will fit all industry, but in every instance a team operation is needed and the members of the team should represent every department involved.

Members of this team need not be research trained, but they should be appreciative of research possibilities. Some technical training or practical experience is necessary and so is a business sense of values. Among the qualities desired in a team member are an inquiring mind fertile with ideas, some diplomacy to help get things done without friction, and an "It can be done" spirit.

It helps to locate the mechanical portion of a research project in the production area of a plant so as to take advantage of the facilities and the people. Advanced work can be carried on in the engineering department.

Factors controlling the selection of a project will be limitations in manpower, time, and money. When a project has been approved and the work completed, the results ought to be written up in detail and circularized through all departments involved. This is particularly important when the results call for a change in existing production methods.

(On the panel which developed the information appearing in this article, in addition to the secretary, were H. D. Hall (panel leader), General Motors Corp.; M. L. Schuehle, Aero-Space Division, Boeing Aircraft Co.; Paul Holmes, Republic Aviation Corp.; Robert Parrett, American Hardware Corp.; and Henry Little, Arthur D. Little, Inc.)

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(This article is based on a report of one of four panels on aircraft production subjects. All four are available as a package as **SP-331. See order blank on p. 6.**)

Canadair Readies New Cargo Aircraft

Based on paper by

K. H. LARSSON
Canadair

THE CANADAIR 44, a turboprop cargo aircraft scheduled to go into operation next year, represents a completely new design, although based on the Bristol Aeroplane Co.'s CL-28. It is powered by four Tyne engines for economical operation in the 18,000–24,000-ft altitude range, and will carry a net payload of 30.4 tons for a range of 3050 statute miles at an average speed of 350 mph.

The fuselage incorporates a swing tail section to permit straight-in loading from the tail. A mechanical loading system has been developed to facilitate a systems approach to cargo handling. The target in design of the system has been the unloading and loading of a full payload within an hour.

Conventional pallets and containers are used, together with a chain drive mechanism, as shown in Fig. 1. The pallets weigh 140 lb each and, since they are less than an inch thick and slide directly on the floor, there is little cube loss. It is anticipated that this mechanized loading will give 10 aircraft the same annual productivity as 18 manually loaded ones.

Two other versions of the Canadair 44 are projected. One will carry a heavier payload but at some sacrifice of range; the other will have both payload and range increased to meet requirements for transatlantic use.

To order Paper No. 170B . . . from which material for this article was drawn, see p. 6.

Cutting Tool Trends May Mold Metalworking Future

Based on report by secretary

ROBERT F. HUBER
Steel Magazine

THREE MAJOR TRENDS in cutting tools that could change the look of metalworking in the future are:

1. The advent of the ceramics.
2. The creation of the super high-speed steels.
3. The titanium carbides.

These advances are expected to help production men step up their machining efficiency via better tool life at faster cutting speeds.

Ceramics appear to have found a niche in four metal removal areas: (1)

continued on page 124

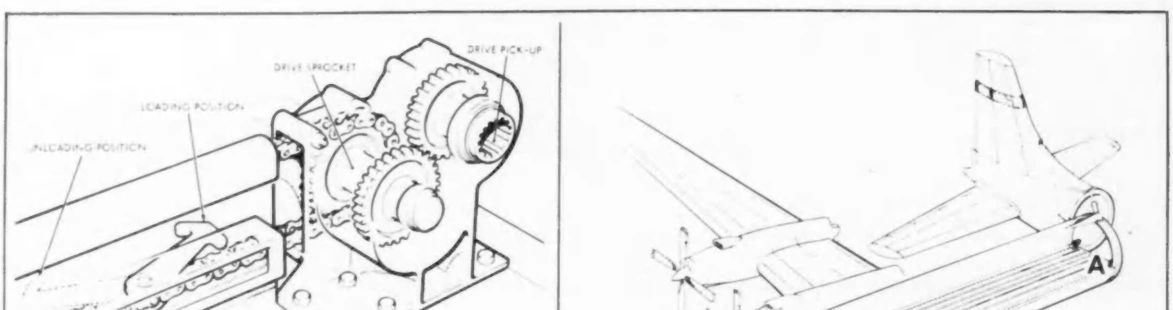


Fig. 1 — Cargo handling mechanism of the Canadair 44 designed to load and unload a 30-ton, palletized payload within an hour's time.

Glass Engineered for Special Purposes

Based on talk by

GEORGE W. McLELLAN

Corning Glass Works

(Presented before SAE Southern New England Section)

GLASS is chemically a mixture of oxides, usually a combination of silica with various fluxing agents or combinations of such agents. Some 70,000 different formulas have been melted and of these there are about 600 available commercially. They can be classified by composition into six broad categories, as shown in Table 1. In all types except fused silica there are several compositions.

Thermal expansion coefficient plays a critical role in the ability of glass to resist thermal stress resulting from local heating or sudden change in temperature. The high-expansion types, soda-lime and lead-alkali, should not be used where resistance to thermal shock is important. On the other hand, 96% silica and fused silica are practically indestructible. Their resistance to thermal shock and ability to operate at sustained temperatures near 1700 F make these compositions useful for furnace observation ports and windows for hypersonic wind tunnels.

Table 1 — Properties of Representative Glasses

Type of Glass	Soda Potash Lead (No. 0010)[a]	Soda Lime (No. 0080)	Borosilicate (No. 7740)	Alumino Silicate (No. 1720)	96% Silica (No. 7900)	Fused Silica (No. 7940)
Thermal Expansion Coefficient Per Deg F	50.6	51.1	18.1	23.3	4.4	3.1
Upper Working Temperature, F						
Annealed						
Normal	230	230	446	392	1472	1652
Extreme	716	860	914	1202	1994	2012
Tempered						
Normal	—	428	500	752	—	—
Extreme	—	482	554	842	—	—
Log_{10} Volume Resistivity						
482 F	8.9	6.4	8.1	11.4	9.7	12.2
652 F	7.0	5.1	6.6	9.5	8.1	10.4
Power Factor (1 mc, 68 F)	0.0016	0.009	0.0046	0.0038	0.0005	1.11111
Dielectric Constant (1 mc, 68 F)	6.7	7.2	4.6	7.2	3.8	3.8

[a] Number designations refer to specific Corning compositions.

Fig. 1 — Structure of semibright nickel, bright nickel, and chromium plate on steel (reduced from photomicrograph taken at 1000×). Etched with nitric acid. This shows the correct columnar structure of the semibright nickel and lamellar structure of the bright nickel for best protection.

Ways to Improve Plated Parts Service

Based on paper by

D. M. BIGGE

Chrysler Corp.

MUCH better performance can be had from chromium platings by using semibright plus bright nickel in multilayer coatings than by increasing the thickness of the semibright or bright nickel in a single nickel layer.

The ratio of thickness of semibright and bright nickel is important, especially on steel parts subject to impact, such as bumpers and bumper guards. The bright nickel thickness should be limited to 25% of the total nickel thickness. The greater thickness of the more ductile semibright reduces the tendency of the plate to fracture through its entire thickness on impact. On zinc die-cast, decorative parts, the thickness of the bright can be one-third of the combined thickness of the nickel layers.

How to Check Pitting

Depositing a bright nickel containing sulfur on a sulfur-free, semibright nickel gives the best corrosion resistant performance. The pitting on bright nickel, which progresses continuously to the base metal, sharply slows its rate of penetration at the interface of the nickel layers and then proceeds laterally more slowly with a reduced rate of vertical penetration.

Fig. 1 shows the typical structure of the semibright, bright nickel, and chromium plate. Semibright nickel should have a columnar structure, as shown, for good corrosion protection. The bright nickel layer should be lamellar. Protection is inferior when the semibright has a banded structure.

To Order Paper No. 147A . . . from which material for this article was drawn, see p. 6.

SAE NEWS

A report from the BOARD OF DIRECTORS

At the June 10, 1960, meeting of the Board of Directors, the following actions were taken:

APPROVED

New schedule of **NONMEMBER REGISTRATION FEES** at national meetings (**Summary 1**)

AFFILIATION of six SAE Sections with local engineering Society groups. (**Summary 2**)

Establishment of a **FOX VALLEY DIVISION** under the Chicago Section. (**Summary 2**)

Change in **TITLES FOR SECTIONS' VICE-CHAIRMEN.** (**Summary 2**)

Elimination of one Vice-Chairmanship and creation of another on **WASHINGTON SECTION'S** Governing Board. (**Summary 2**)

New SAE Student Branch at **MILWAUKEE SCHOOL OF ENGINEERING.** (**Summary 2**)

Society guarantee to employees against undue tax penalty on annuity from **STAFF RETIREMENT PLAN.** (**Summary 3**)

First step in procedure to broaden scope of technical area for papers eligible for **MANLY MEMORIAL MEDAL.** (**Summary 4**)

Addition of a fifth participating society in the **ELMER A. SPERRY AWARD.** (**Summary 5**)

APPOINTMENT OF EIGHT SAE MEMBERS to Society posts by President Chesebrough. (**Summary 6**)

Election to **SAE MEMBERSHIP** of ninety-seven applicants. (**Summary 6**)

REJECTED

Twenty-six applicants for **MEMBERSHIP.** (**Summary 6**)

"A summary report of the actions of the Board of Directors shall be published in the next following issue of the official publication of the Society."
. . . from C 6 of the SAE Constitution.

①

Change Meeting Fees For Nonmembers

The Directors approved the recommendation of the Engineering Activity Board that registration fees for Nonmembers at SAE National Meetings be established as follows:

Length of Meeting	Daily Registration Fee	Meeting Registration Fee
5 days	$3.00	$12.50
4	3.00	10.00
3	3.00	7.50
2	3.00	5.00

The first meeting at which this new plan will become effective is the SAE National West Coast Meeting, to be held in San Francisco, August 16–19, 1960.

Approval of the new schedule for Nonmember registration fees also included the provision that a Nonmember may apply it toward his initiation fee, if his membership application is received within three months.

②

Section Affiliations Reaffirmed

The following Sections were authorized to continue their affiliations with local engineering society groups for another year.

- Baltimore Section with Engineers Club of Baltimore.
- Cincinnati Section with Engineering Society of Cincinnati and Scientific and Technical Societies Council of Cincinnati.
- Cleveland Section with Cleveland Technical Societies Council.
- Detroit Section with the Engineering Society of Detroit and Toledo Technical Societies Council.
- Northern California Section with Santa Clara Valley Engineers Council.
- Philadelphia Section with Engineers Club of Philadelphia.

The above action was one of several proposals of the Sections Board accepted by the Directors. Others recommended by the Sections Board and approved by the Directors are:

1. Authorization of the Chicago Section to establish a Fox Valley Division to serve its members in the area of Aurora, Elgin and Joliet.
2. Change in the names of Sections' Vice-Chairmen to conform with the names of corresponding committees of the Engineering Activity Board. (Most Section Vice-Chairmen titles have been patterned after the names of twelve professional activity divisions which existed before the recent amendment of the SAE Constitution and By-Laws.
3. Authorization of the Washington Section to discontinue the Vice-Chairmanship representing Engineering Materials and to add a Vice-Chairman representing Ground Support Activity.
4. Authorization of the SAE Student Club at the Milwaukee School of Engineering as a Student Branch.

③

Retirement Plan Strengthened

The Society will guarantee each employee that, upon his retirement, his estate will not suffer unnecessarily taxwise if the Society's plan should be ruled unqualified at some future date. This action, taken by the Directors, upon recommendation of the Finance Committee, affects only those employees who select the Joint and Survivor Plan for their retirement annuity.

The Society has not filed for qualification of its plan with the Internal Revenue Service because its tax-exempt status makes it unnecessary to do so, according to the SAE legal counsel. The action of the Directors is aimed at protecting the intent of the retirement plan.

④

Changes Proposed in the Manly Memorial Medal Award Rules

The first step has been taken by the Directors to modify the rules of the Manly Memorial Board of Award, as recommended by that Board.

When originated, this Award was limited in scope to aircraft powerplants of the piston type.

The Board of Award has since found it necessary to broaden the scope of the Award to make more SAE papers eligible for the Award. The language of the Award rules has been modified to include new forms of propulsion that have been developed in the aerospace age.

The Directors must take final action on this proposal at a forthcoming meeting for the proposed amendment to become effective. It is anticipated that this matter will be brought up for consideration at the next Directors' Meeting in September.

(5)

Sperry Award Rules Amended

The Directors approved the recommendation that a fifth participating Society be added to the four currently co-sponsoring the Elmer A. Sperry Award. The new Society is the Institute of the Aeronautical Sciences. The four Societies already represented on the Award Board are: the American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Naval Architects and Marine Engineers, and the Society of Automotive Engineers.

The Elmer A. Sperry Award has as its objective ". . . the recognition of a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea, or air."

(6)

Other Actions of the Board of Directors

The Directors confirmed President Chesebrough's appointment of the following committee personnel:

L. Ray Buckendale Lecture Committee

- P. H. Pretz, Chairman
  Director, Test. Operations Office, Engineering and Research, Ford Motor Company
- H. O. Flynn, Assistant Chief Engineer, Truck Chassis and Body, Chevrolet Motor Division, GMC
- E. P. Lamb, Executive Engineer, Engineering Division, Chrysler Corporation
- R. C. Norrie, General Manager, Kenworth Motor Truck Company, Division of Pacific Car and Foundry
- E. F. Petsch, Assistant Sales Manager, Transmission and Axle Division, Rockwell-Standard Corporation

Technical Board

- J. F. Adamson, Chief, Engineer, Automotive Division, American Motors Corporation — to serve until the end of the 1961 administrative year, to fill the unexpired term of D. Roy Shoults, who has resigned.
- J. H. Dolan, General Manager, Mechanical Department, Burlington Truck Lines, Inc. — to serve until the end of the 1961 administrative year, to fill a previously unoccupied term of service.

At the request of President Chesebrough, the Directors confirmed the appointment of Henry L. Brownback as Advisor to the President for the 1961 SAE International Congress and Exposition of Automotive Engineering.

The Directors acted favorably on 97 applications for Membership, and also denied Membership to 26 applicants.

SAE NATIONAL MEETINGS

1960

- **September 12–15**
  National Farm, Construction and Industrial Machinery Meeting (including production forum and engineering display), Milwaukee Auditorium, Milwaukee, Wis.
- **October 10–14**
  National Aeronautic Meeting (including manufacturing forum and engineering display), The Ambassador, Los Angeles, Calif.
- **October 25–27**
  National Transportation Meeting, Hotel Leamington, Minneapolis, Minn.
- **October 31–November 2**
  National Powerplant Meeting, Sheraton-Cleveland, Cleveland, Ohio.
- **November 2–4**
  National Fuels and Lubricants Meeting, The Mayo, Tulsa, Okla.

1961

- **January 9–13**
  SAE International Congress and Exposition of Automotive Engineering, Cobo Hall, Detroit, Mich.
- **March 13–17**
  National Automobile Week (including National Production Meeting), The Sheraton-Cadillac, Detroit, Mich.
- **April 4–7**
  National Aeronautic Meeting (including production forum and engineering display), Hotel Commodore, New York, N. Y.
- **June 4–9**
  Summer Meeting, Chase-Park Plaza, St. Louis, Mo.

Directors to Speak Before Society Units

ELEVEN members of the Board of Directors (each an authority in his field) are prepared to talk before SAE Sections, Groups, Student Branches, and Clubs . . . according to a report made at the June Board of Directors meeting.

These Directors — who, so far, have answered President Harry E. Chesebrough's call for assistance in responding to Section requests for a Presidential visit — are: William K. Creson, Gregory Flynn, Jr., Joseph Gurski, R. R. Higginbotham, J. R. MacGregor, R. R. Noble, William Petring, Leonard Raymond, W. F. Shurts, Gilbert Way, and J. S. Wintringham.

Of these, eight are offering specific papers, as follows:

Product Quality .... Creson

GMR Stirling Cycle Engine ... Flynn

Laboratory Control of Automotive Materials .... Gurski

Expansion of SAE Aeronautical Activity into Aerospace Field .... Higginbotham

Winter Driving .... Petring

Engineering Developments in Cars; New Automotive Powerplant Developments; Technical and Commercial Aspects of European Automotive Industry .... Raymond

Utilization of Fuel Antiknock Value by Automotive Engines .... Way

Potential Automobile Powerplants .... Wintringham

Some have volunteered to address up to six Sections and Student Branches. . . . Three have indicated they will speak before most any Society unit, limited only by extreme geographical distances.

Sections, Groups, and Student Branches have been informed of the availability of these Board members for speaking assignments, and have been asked to make direct arrangements with them.

FACTS . . .

. . . from SAE literature

(Except where a charge is specifically indicated, SAE Journal will be glad to supply on request one copy of any of the pieces of SAE literature described. Address "Literature," SAE Journal, 485 Lexington Ave., New York 17, N. Y.)

HOW AND WHERE the various nonferrous metals are used in ground vehicles and aerospacecraft is defined in one section of the new booklet titled "SAE Journal Readers Specify Nonferrous Metals."

IDEAS are what the newest Student Branch booklet offers to SAE Student Branch officers.

The paragraphs on "Meeting Subjects," "Projects," the "Field Trip," "Attendance Spurs," "Special Events," "Social Events," "Membership Drives," provide the basic "know-how" for integration into regular Branch activities.

The booklet is titled "SAE Student Branch 'Ideas' " and was developed by F. B. Esty, Sections Board member, who is active on the Board's Student Activities Committee. The booklet is being distributed to SAE Student Branches and is available to others who are interested.

YOU'LL . . .

be interested to know . . .

DUST — 40 lbs of it — was what an air filter manufacturer in Johannesburg, South Africa, formally requisitioned from SAE just recently. For details, see p. 112 in this issue.

THE 1960 SAE SUMMER MEETING — held in Chicago last June — was the first ever to be held in a large city rather than at a summer resort . . . and its total attendance (2087) outstripped that of any previous Summer Meeting.

Next largest Summer Meeting was in Atlantic City in 1956, when 1471 members and guests were registered. (Atlantic City was the site for SAE Summer Meetings from 1952 through 1959.)

Largest of the Summer Meetings at French Lick Springs, Indiana, (from 1946 through 1951), clocked an attendance of 1400.

NEXT YEAR, the 1961 SAE Summer

Ackerman Chairmans Congress Operations Committee

Paul C. Ackerman

PAUL C. ACKERMAN — who stated recently that "One of the most significant services SAE offers is the opportunity for interaction among active, creative engineering minds" — is piloting the Operations Committee for next January's International Congress and Exposition of Automotive Engineering, in Detroit's new Cobo Hall.

Ackerman has appointed R. E. Johnson to head an Overseas Luncheon Subcommittee; Oliver K. Kelley, a Plant Tours Subcommittee; Alex L. Haynes, a Science Pavilion Subcommittee; Sam Petok, a Publicity Committee; L. E. Fleuelling, an Attendance Promotion Subcommittee . . . and Charles C. Dybvig is heading the Dinner Subcommittee which he chairmanned last year.

Johnson's Overseas Luncheon Subcommittee is projecting a function that will **do honor to the overseas Congress participants** — with a principal speaker (or speakers) and a list of special guests.

Kelley's Plant Tours Subcommittee is arranging for suitable **group tours** from the wealth of available sites in the Detroit area.

Haynes' Science Pavilion Subcommittee is developing a **noncommercial display** of the newest in engineering concepts for exposition in the Science Pavilion — to tie in with the "breakthrough" sessions.

Petok's Publicity Subcommittee — cooperating with the Attendance Promotion Subcommittee — is working out means whereby the Congress, with the Society and its officers and members, will receive **industry-wide recognition.**

Fleuelling's Attendance Promotion Subcommittee is setting its sights toward attracting to the Congress the maximum **attendance** warranted by the many and varied events planned.

Dybvig's Dinner Subcommittee is lining up details of the **banquet** scheduled for Wednesday night of Congress week.

. . . . And a Reception Committee — composed largely of Detroit Section members — will be on hand for the entire week of the Congress (which constitutes SAE's 1961 Annual Meeting).

Meeting will be at the Chase-Park Plaza in St. Louis.

MEMBERSHIP CHAIRMAN W. J. LUX, writing of SAE Standards and Technical Reports, said recently: "Sure, you can buy them if you wish, but the real winners are those who worked on the committees who set up the standards, wrote the reports, and made them practical and useful. They have worked together to solve their common problems. Next year, with *your* help, they may ease one of your bad headaches."

SECTION TREASURERS have received the new Sections Financial Analysis and Budget Form, and its complementary, revised Monthly Report Form from Sections Board Chairman W. F. Ford.

The new forms were devised by the Section Finance Committee of the Sections Board to provide uniform means for preplanning Section income and expense . . . and to assist treasurers in keeping Governing Boards periodically informed of Sections' financial status.

PRETZ . . .

. . . heads committee for Buckendale Lectures

PHILIP H. PRETZ now chairmans the L. Ray Buckendale Lecture Committee, by confirmation of the Board of Directors at its June meeting.

Serving with Pretz are committeemen H. O. Flynn, E. P. Lamb, R. C. Norrie, and E. F. Petsch.

The L. Ray Buckendale Lectures provide for a cash award and certificate for an annual lecture and monograph by a distinguished authority in the technical areas of commercial or military ground vehicles. The "plan" stresses that each lecture — while emphasizing the practical aspects of the topic — be directed toward the needs of young engineers and students.

Philip H. Pretz

3 Membership Groups Seek NEW, Separate Goals

In this article, appears news about:

Peter Altman, vice-president and technical consultant, Continental Motors Corp.

William J. Lux, supervising engineer, research department, Caterpillar Tractor Co.

Norman P. Mollinger, sales engineer, Ladish Corp.

Phillip S. Myers, professor of mechanical engineering, University of Wisconsin

Russell W. Rand, staff engineer, research department, Caterpillar Tractor Co.

William F. Sherman, manager, engineering and technical department, Automobile Manufacturers Association

Walter E. Thill, chief engineer, Federal-Mogul Service Div., Federal-Mogul-Bower Bearings

NORMAN P. Mollinger, Walter E. Thill, and and William F. Sherman are heading three major subcommittees through which the SAE Membership Committee aims for action this year.

Norman P. Mollinger (left) and Art Kortheuer, manager, membership promotion, SAE Headquarters staff.

Mollinger's group (Sections Membership Program Subcommittee) will work through and with the membership chairmen of the various Sections. They will develop and sponsor improved procedures for stimulating increases in SAE membership. An immediate project is to help implement through Section membership committees the new "Pilot Program" inaugurated this year by Membership Committee chairman William J. Lux. This program (see p. 103, SAE Journal, June, 1960) provides a new approach to member prospects, using a personal invitation as a prime weapon. It emphasizes personal contact and individually-directed effort . . . and has already been put in action in Metropolitan, Chicago, and a few other areas. Membership Committee sponsor for this group is Russell W. Rand.

Thill's group (the Engineering Activity Membership Program Subcommittee) seeks to develop membership potential by appealing to and through Activity interests. Their approach is expected to reach men who may not be known readily to Section membership committees . . . and also the "Out-of-Section" areas.

Currently Thill's group is planning new membership promotion brochures to reach areas of engineering interest not yet covered by existing promotion booklets. Membership Committee sponsor for this group is Phillip S. Myers.

The Sherman group (Technical Membership Program Committee) is devoting itself exclusively to promotion of membership among engineers serving on SAE technical committees, who are not members of the Society. Membership Committee sponsor for this group is Peter Altman.

Walter E. Thill

Henry L. Brownback

Brownback Named Advisor to SAE President

HENRY L. BROWNBACK has been named by SAE President Harry E. Chesebrough as Presidential Advisor in connection with the 1961 SAE Annual Meeting which is being designated as the SAE International Congress and Exposition of Automotive Engineering.

The "International" designation reflects the unusual emphasis to be placed on exchange of technical information with the scores of foreign engineers scheduled to attend . . . and, in many cases, present papers.

Brownback has been chosen for this post of honor because of his great knowledge about overseas technical operations and his wide acquaintance with automotive engineers throughout the world. On many occasions during the last 20 years, he has been SAE's unofficial ambassador at a variety of technical meetings, congresses, and conferences in France, Germany, Italy, Holland, Scandinavia and other European areas.

Brownback, who retired recently as a technical consultant to Renault in France, holds numerous European patents which cause him to divide his time between Europe and his home at Deer Isle, Maine.

When you want an SAE Consultant...

. . . there are 141 SAE members ready for on-call, part- or full-time consulting work throughout the United States and Canada and in lands as far away as the Belgian Congo. These are listed in the 1960 issue of SAE CONSULTANTS which has been released by the SAE Placement Service.

Various engineering areas are covered, with general to specialized experience. The member's background is given along with his name, address and telephone number for speedy direct contact.

Send for your copy of SAE CONSULTANTS *now* so that you will have it handy when the need arises. It is available, free of charge, from the SAE Placement Service at headquarters.

Erratum—
Mid-Continent Section Members' Travel Survey

The significance of two tabulations was incorrectely stated in the item about Mid-Continent Section's members-meeting-travel survey on p. 102, June, 1960 SAE Journal.

(The survey was designed to show the number of miles traveled, and the number of cars necessary to carry the members to the Section's meetings in each of the cities where such meetings are held.)

Following is a clarification of the meaning of the two tabulations:

If out-of-towners were to arrive in any of the following cities on a four-members-to-a-car basis, and if each local member were to come alone in his own car, then:

Cushing	could expect	42 cars
Ponca City		51
Oklahoma City		63
Bartlesville		70
Tulsa		94

If each member were to travel independently, however, the total miles traveled would be:

8,800	for	Tulsa
12,300	for	Cushing
12,600	for	Bartlesville
15,300	for	Ponca City
17,000	for	Oklahoma City

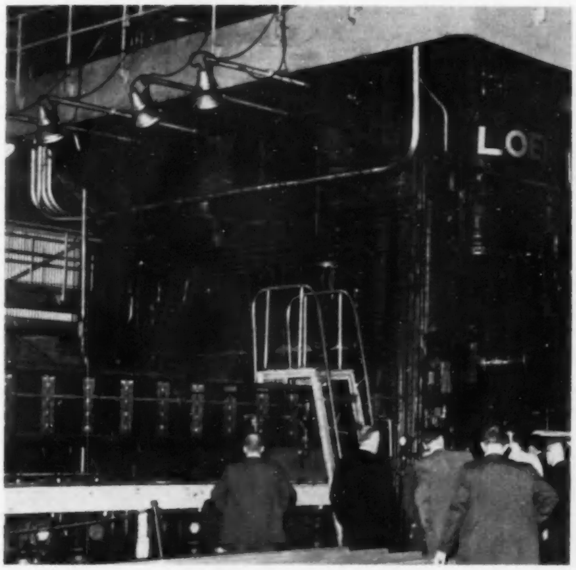
120 Engineers Tour Reynolds Rolling Mill

120 ENGINEERS saw what goes on in the Reynolds Metals' Sheet and Plate Rolling Mill in McCook, Ill., during the SAE Summer Meeting in Chicago.

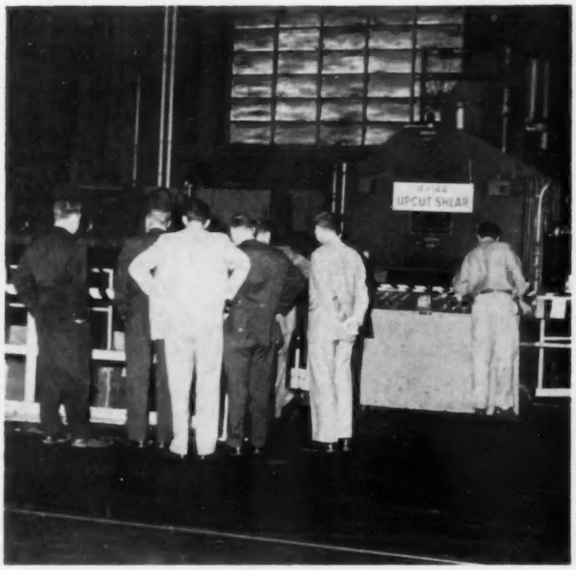
Tour highlights included a visit to the cast house as well as to hot breakdown, plate, and cold rolling mills.

PRIOR TO COILING, aluminum travels down 500-ft run-out tables where air is blown across it.

ALUMINUM INGOTS are cast by means of a direct chill process. The three at right will eventually be reheated and rolled into sheet or plate.



A 145 IN. REVERSING MILL, where hot slabs of aluminum are rolled into plate, captured the attention of everyone . . .



. . . as did an **ULTRASONIC TESTING TANK** where aluminum plate is tested to meet the rigid requirements of aero-space industries.

TREADING OF ALUMINUM PLATE is described by one of the tour hosts who were on hand to answer questions.

FINISHED HARDWARE was later inspected by tour members.

SAE LETTERS FROM READERS

From:

Evan L. Jones (M'55)
12017 Rosemont
Detroit 28, Mich.

Dear Editor:

The first copy of my paper Preprint No. 208C came to me in Friday's mail. I was pleased with the general arrangement of the paper.

In the process of proofreading, I discovered that someone at SAE had found and corrected errors in equations (7) and (9) that had not been detected in the original typed copy here. The Greek letter "pi," for the constant 3.14159, had been left out of the two equations here.

I was delighted to find that the error had somehow been detected and corrected in the published paper.

"Oh, what is so rare as a letter of praise!
This above all doth brighten our days.
Too many authors throw brickbats and stones,
But nothing like that from Evan L. Jones."

— For the SAE Headquarters staff, by Sylvia Thomas, manager, Programming Dept.

From:

B. H. Vanderveen
c/o Vosseveldlaan 6a
Soest, Holland

Dear Editor:

The story in your March 1960 issue concerning the late Delmar G. Roos, who was one of the most important people connected with development of the U. S. Army Jeep, caught my attention, as I am very interested in Jeeps and Jeep-like vehicles.

I was also highly interested in the article "The M151, A New ¼ Ton Mutt" which appeared in the April issue of SAE Journal. Although I have some data and pictures of its prototype, the XM-151, and a picture of the Mutt in its present form, I found the technical specification and description in your magazine very interesting.

I have quite an extensive file of photographs and literature on Jeeps, Jeep-like vehicles, and other types of military vehicles. I would like to add to my collection, and would appreciate it very much if any military or semi-military readers of SAE Journal would help me obtain additions, such as books, booklets, photos, clippings, or any other pictorial material.

I thank SAE Journal for publishing this request and, anyone who is kind enough to send me any material pertaining to military wheeled, half-tracked and full-tracked vehicles.

From:

M. F. Gates, Senior Research Engineer
Propulsion Dept., Advanced Research Div.
Hiller Aircraft Corp.
Palo Alto, Calif.

Dear Editor:

I believe you have reversed the captions on figures 2 and 3 in your lead article "Six Ways to Lift an Air Cushion Vehicle" of the March 1960 SAE Journal, pg. 26–29. We originally proposed this configuration as was pointed out by Dr. Boehler in his paper 133A on which you are drawing for your article. Our disclosure of this concept was in a paper presented at the Princeton GEM Symposium.

The most important advantage of this concept has not been presented. This advantage is that the basic jet energy is conserved in the Hiller diffuser-recirculation concept while in the conventional annular jet and air leakage type GEM's, this is not the case.

OUR MISTAKE! The captions for Figs. 2 and 3 of the article "Six Ways to Lift an Air Cushion Vehicle" were transposed on page 27 of the March 1960 SAE Journal. . . . Below are the figures and captions as they should have appeared:

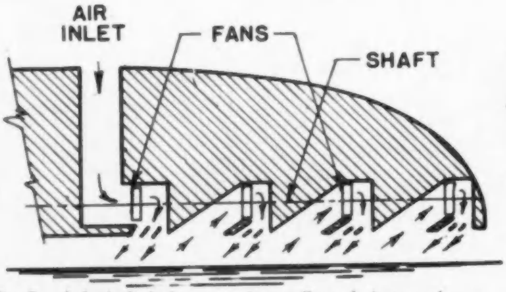


Fig. 2 — Labyrinth design uses viscous flow of air to seal pressure under vehicle.

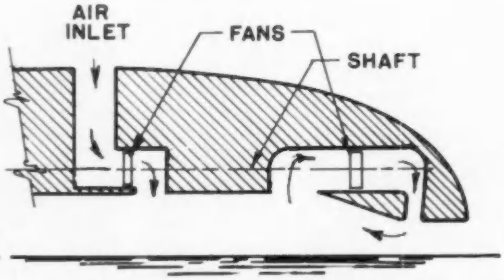


Fig. 3 — Diffuser design uses conversion of dynamic to static pressure by diffuser action to seal high-pressure air under vehicle.

SAE MEMBERS

WAYNE H. WORTHINGTON, who has been a long time official of John Deere Research & Engineering Center, Deere Mfg. Co. and is currently director of engineering for the company's German subsidiary Heinrich Lanz A.G., was one of three distinguished alumni of Oklahoma State University who were inducted into the OSU Alumni Hall of Fame on May 29.

He is a Past SAE Director and is now a member of SAE's International Information Committee.

E. S. STARKMAN, previously associate professor, has been named professor of mechanical engineering at the University of California.

Starkman is a recepient of the 1959 Horning Memorial Award.

DR. ALFRED K. WRIGHT, vice-president for operations at Tung-Sol Electric, Inc., has been elected to the company's board of directors.

Dr. Wright received a "Citation for Distinguished Attainment" on April 21 from Northeastern University during exercises commemorating the 50th anniversary of the College of Engineering and its cooperative engineering program.

A. V. PILLING, vice-president of Lawrence Aviation Industries, Inc., has been appointed to the Department of Defense Small Business Industry Advisory Committee for a term of two years, sponsored by U. S. Army.

NORMAN SHIDLE, editor of *SAE Journal*, has been re-elected to a three year term as a Trustee of Engineering Index.

CAPTAIN JOHN JAY IDE, USNR, has been awarded the cross of Chevalier of the Legion of Honor by the French Government. For 20 years Ide was stationed at the American Embassy in Paris as European Representative of the National Advisory Committee for Aeronautics. Later he was stationed in London as Assistant Naval Attaché for Air. For the last year he has been president of the Federation of French Alliances in the United States, and is currently vice-president of the Fédération Aéronautique Internationale.

JOSEPH GILBERT, SAE Secretary and General Manager spoke recently to the Conference of Engineering Society Secretaries on "Long Range Planning — Procedures and Techniques."

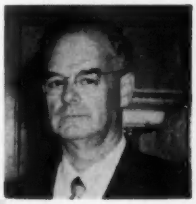
VIRGIL L. SNOW has been named general manager of Euclid Division of General Motors Corp. succeeding **Raymond Q. Armington.**

Snow, who joined the company in 1935, has been director of engineering for Euclid since 1958.

RAYMOND Q. ARMINGTON is retiring as general manager of Euclid Division of General Motors Corp. to devote full time to family interests.

He has been associated with Euclid since it was formed in 1931 from a unit of a firm founded by his father. He was general manager of the company from 1945 to 1951, when he became president. He was named general manager of Euclid when the firm became a division of General Motors.

— continued —


Worthington


Starkman


Wright


Pilling


Ide

Willey Receives Honorary Degree

Willey

ARTHUR OSGOOD WILLEY has received the honorary degree of Doctor of Engineering from the University of Maine.

Willey is a graduate of the University of Maine, received his master's degree from there, and was a teacher at the University for five years. He was a member of the faculty of Case School of Applied Science for eleven years, rising to the rank of associate professor. In 1940 he became director of research for Lubrizol Corp., and is now executive vice-president of the corporation.

The citation reads, "In recognition of your achievements as a successful teacher, corporation executive, and director, whose industry and ability have made you one of the foremost authorities in the world on automotive engineering lubrication."

HAROLD G. WARNER has been appointed general manager of Cadillac Motor Car Division, General Motors Corp. He had been works manager at Cadillac since 1955.

ROBERT J. DUBUC has been appointed general quality manager, automotive components at Bendix Products Division of Bendix Corp. He has been staff assistant to automotive general manager of Bendix Products Division since 1959.

He is a member of SAE Special Projects Committee.

DUNCAN B. GARDINER has been appointed manager of corporate engineering for Vickers, Inc. He had been director of research and development since 1956.

RENE C. McPHERSON has been elected executive vice-president of Hayes Steel Products, Ltd., a partially owned affiliate of Dana Corp.

McPherson has been manager of Auburn Division of Dana Corp. for the past several years. Prior to assuming that position, he was axle sales manager at Dana's headquarters in Toledo, and sales engineer covering the major automotive manufacturers.

CHARLES H. KANAVEL has been named Detroit manager of equipment sales for B. F. Goodrich Co. For the past four years he has been national field sales manager in the company's Aviation Products Division.

ALGER R. JOHNSON has joined FWD Corp. as project engineer. Formerly he was reliability engineer for Bendix Systems Division, Bendix Corp.

ANTHONY A. PACK has been appointed vice-president and general manager of Recony Division of Vinco Corp. He was formerly with the Hamilton-Standard Division of United Aircraft Corp. in executive, administrative and engineering capacities related to military ground support equipment.

W. J. LEE, former director of tire engineering, has been appointed director of tire research and development for Goodyear Tire & Rubber Co.

Lee has been associated with tire design and engineering projects during most of his career. For eight years, he was resident engineer in Detroit for Goodyear.

A. H. EASTON, professor of civil and mechanical engineering at the University of Wisconsin, is the author of, "Performance Studies of Straight Trucks and Truck Tractor Semitrailer Units," published by the University of Wisconsin Engineering Experiment Station as Report No. 6.

T. C. DuMOND has been appointed manager, national and regional metal congresses, American Society for Metals.

He will also direct ASM's membership and chapter relations, providing liaison, counsel and direction from ASM headquarters to the Society's members and Chapters.

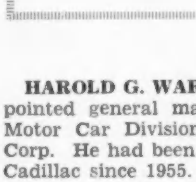
In his Metal congress function, he will work with national ASM committees in selecting subjects and titles for papers and panels, and in obtaining authors, speakers and session chairmen.

DuMond is also editor of *ASM Transactions* and *Metals Review*, the newsdigest monthly for ASM members.

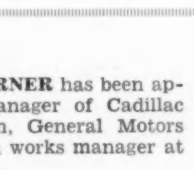
CHARLES E. HEITMAN, JR., former president of Carter Carburetor Division of ACF Industries, Inc., recently joined the staff of **George E. Stoll**, executive vice-president, Bendix Corp.

In this capacity, Heitman has responsibility for major manufacturing and organizational functions in the divisional and inter-divisional areas.

HAROLD P. SCHALLER has been named general sales manager of United Motors Service Division of General Motors Corp. He had been assistant general sales manager of UMS in charge of the western half of the U. S.



Warner



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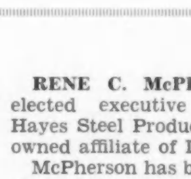
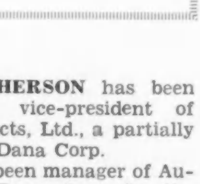
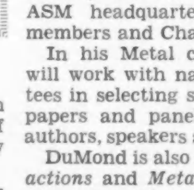


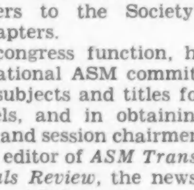
Gardiner



McPherson



Pack



Lee

M. G. BEKKER, technical director for United States Army Ordnance Tank & Automotive Command, announces that the First International Conference on the Mechanics of Soil-Vehicle Systems will be held in Turin, Italy in 1961.

The Conference is being organized by the Turin Institute of Technology in cooperation with the Universities of Milan, Bologna, Rome and Naples under the auspices of the Italian Army, National Research Council and the United States Army Office of Ordnance Research, Duke University.

Bekker is national secretary for the Conference.

H. C. GREBE has been appointed chief engineering consultant for Ford Motors Co.'s Metal Stamping Division. Formerly chief engineer of the division's product and production engineering office, Grebe's reassignment was made at his own request for medical reasons.

HERBERT L. MISCH has been appointed chief engineer of product and production engineering of Ford Motor Co.'s Metal Stamping Division, succeeding **H. C. Grebe.**

Misch joined Ford in 1957 as assistant chief engineer at Lincoln-Mercury Division. Last November, he was appointed executive engineer, current car, in the Ford Division product engineering office.

EUGENE E. McMANNIS, chief engineer for tire design research at Goodyear Tire & Rubber Co., has received one of the company's three R. P. Dinsmore Awards of Merit for 1960.

The awards, named for the company's vice-president, research and development, are presented each year to individuals in research and development who are recognized for their original thinking and cooperative action in developing a better product. McMannis was cited for his work in developing a new design in ultra-high-speed tires.

ROY C. CONNER, general manager of Mobile Hydraulics Division, Vickers, Inc., has been elected a vice-president of the company.

— continued —

McMannis

Conner

Portrait Unveiled at Colwell Center Dedication

WHEN Thompson-Ramo-Wooldridge dedicated its new Colwell Engineering Center, this portrait of Arch T. Colwell, in whose honor the Center is named, was unveiled (see SAE Journal, April 1960, p. 110). The work of Edith Stevenson Wright, the portrait will hang permanently in the lobby of the new two-story engineering building, which is the first unit in a $5,000,000 building program.

Under Colwell's direction as vice-president-engineering, research, and development of TRW, it was brought out at the dedication ceremonies, the company engineered itself from humble beginnings into a top-ranking position among suppliers of precision products to automobile and aircraft builders.

Colwell was president of SAE in 1941, is currently chairman of this Society's Finance Committee . . . and has contributed greatly to the affairs of other important technical societies.

He was awarded an honorary degree of Doctor of Engineering by Case Institute of Technology in 1953, was made an honorary alumnus of Fenn College in 1956, and received in 1957 the Distinguished Service Award from the Cleveland Technical Societies Council.

Born at Yankee Jims, Calif., Colwell attended the University of California Junior College and was graduated from West Point in 1918 with a B.S. degree. This was followed by a C.E. degree from the next two years spent at the U. S. Army Engineer School, Fort Humphreys, Va.

Currently, Colwell is devoting much of his attention to TRW's expansion in automotive fields in South America and in Europe.

SAE Father and Son

Senior

Junior

ROBERT SERGESON, JR. is shown with his father **ROBERT SERGESON, SR.**, an SAE member since 1939. The younger Sergeson graduated from the University of Michigan in 1949, served in U. S. Army in Korea in 1951, and is presently a salesman for White Motor Co. The senior Sergeson is chief metallurgical engineer of Stainless and Strip Division of Jones & Laughlin Steel Corp.

W. E. RICE has been appointed chief engineer for advanced engineering at Rockwell-Standard Corp., Transmission & Axle Division. Prior to joining Rockwell-Standard in 1958 as new products engineer, Rice was auto products engineer for Clark Equipment Co.

J. R. DOYLE has become chief engineer for The Cleveland Trencher Co. Previously he was assistant chief engineer for Oliver Corp.

ROBERT G. STROTHER has been appointed manager of field engineering nationally for Magnaflux Corp. Formerly he was Eastern region manager with headquarters in New York.

WILLIAM DeCAPUA recently joined Sprague Devices, Inc. as vice-president and director. Previously he was vice-president and manager of Henney Motor Co., a subsidiary of Eureka Williams Corp.

MUNDY I. PEALE has been elected a director of ACF Industries, Inc.

Peale, who has been president of Republic Aviation Corp. since 1947, joined that company in 1939 after eight years with United Aircraft Corp. He is also a director of Republic, chairman of the board of Republic Aviation International, and a director of American Can Co. and Royal Netherlands Aircraft Factories, Fokker of Amsterdam.

He has served on the Hoover Commission, the Defense Department's Procurement and Production Advisory Committee, as president of Institute of Aeronautical Sciences and as chairman of Aerospace Industries Association board of governors.

L. C. GATES has joined Ford Motor Co. as product design engineer. Gates resigned as chief engineer, clutches for Long Mfg. Division, Borg-Warner Corp. in September, 1959, after serving the company for 11 years. For a period of seven months, he worked as senior chassis designer for Dodge Truck Engineering, Chrysler Corp.

W. D. COWGILL has been named general sales manager of Cleveland Graphite Bronze Co., Division of Clevite Corp. Cowgill joined the company in 1928, has served in the Detroit sales office since 1939, and has been district sales manager for the past eight years.

WILLIAM C. JACKSON has joined the Martin Co. as chief of test operation. Formerly he was chief engineer for Janke & Co., Inc.

WALTER M. EVANS has joined Thompson-Ramo-Wooldridge, Inc. as senior project engineer. Previously he served the Marietta Division of Lockheed Aircraft Corp. as staff engineer.

CARL J. DEMRICK has been appointed president of Hurd Lock & Mfg. Division of Avis Industrial Corp. Previously he was president of Amplex Division of Chrysler Corp. and vice-president in charge of manufacturing, Plymouth Division.

PETER M. SARLES, manager of materials control at AGT Division, Westinghouse Electric Corp., is studying at Massachusetts Institute of Technology under a 1960–1961 Sloan Fellowship.

F. JAMES SKINNER, president and general manager of Houdaille Industries of Canada, has been appointed a vice-president of Houdaille Industries, Inc.

PETER L. PAULL, assistant manager of Process Division, Texaco Development Corp., has received a patent for improvements in generation of carbon monoxide and hydrogen.

T. W. FLOOD, formerly vice-president, original equipment sales, of Electric Autolite Corp., has been appointed special assistant to president of Willys Motors, Inc.

THOMAS J. CULHANE has joined CRP Foundation Co. as an engineer. Formerly he served Motor Wheel Corp. as research engineer.

GEORGE D. JOHNSON, previously design engineer for Convair, San Diego, is now design engineer for American Airlines.

Rice

Doyle

Strother

DeCapua

Peale

Cowgill

JOHN J. MARTIN has been appointed fuels and lubricants engineer for research laboratories of Denver & RTO Grande Western Railroad. Formerly he was project engineer at Electro-Motive Division of General Motors Corp.

VON DEAN HARRISON has become cost estimator and field engineer for Mechanical Contractors at Fort Wayne. Previously he served Buckeye Pipeing in Lima, Ohio as division products engineer.

FRANKLIN H. SHANK has become drafting manager for Apex Co. Formerly he was design draftsman for Bendix Corp.

RALPH E. KOLDHOFF has been named district sales manager with headquarters at Chicago for Clevite Harris Products, Inc. Previously he was sales engineer in Detroit.

D. A. SHEPARD, executive vice-president and director of Standard Oil Co., spoke on "Petrochemicals in the United States" at a meeting of the société de Chimie Industrielle in Paris, June 8.

LEON R. WOOD has joined Davidson Transfer & Storage Co. as superintendent of maintenance. Previously he was maintenance superintendent for Hertz Corp.

EUGENE LAAS has become hydraulic engineer at Vickers, Inc. Previously he was project engineer at Hamilton Standard Division, United Aircraft Corp.

Obituaries

WALTER G. CHANDLER . . . (M'27) . . . retired assistant general superintendent, Consolidated Edison Co. of N. Y. . . . died July 5 . . . born 1888.

E. P. DeBERRY . . . (M'59) . . . regional fleet manager for Studebaker-Packard Corp. . . . died May 10 . . . born 1913.

ALBERT R. MILLER . . . (M'10) . . . representative for R-B Co., propietor, A. R. Miller Co. . . . died June 18 . . . born 1878.

R. D. NOYES . . . (M'44) . . . national accounts, Union Carbide Plastics Division, Union Carbide Corp. . . . died May 31 . . . born 1912.

R. THEODORE WHITTLETON . . . (M'46) . . . president, Whitnor Chemicals, Inc. . . . died March 24 . . . born 1905.

Rambling . . .

Through The Sections

L. A. Douglass (left) of Cleveland Graphite Bronze Co., Division of Clevite Corp. and Carl S. Ryan of E. I. duPont de Nemours & Co. look over the schedule for **METROPOLITAN SECTION'S** spring social May 13. Douglass is the Section's vice-chairman and Ryan is chairman for 1960–1961.

ALL INDUSTRY IN RUSSIA is based on long term plans which are made in great detail. The Russians know how many engineers will be needed in the future and can break these down into 250 separate categories, Dr. William L. Everitt of University of Illinois, who was recently a member of an exchange mission to Russia, told **CENTRAL ILLINOIS SECTION** May 16.

There is a great desire to enter engineering in Russia and only 25% of the applicants succeed. One-third of the students are women.

Education in Moscow and Leningrad is excellent, Everitt stated, but in other cities it ranges from poor to good.

THE KICK OFF dinner for **CHICAGO SECTION'S** "Pilot Project," which was held June 7 during Summer Meeting, was attended by (left to right) T. J. Jenkins, automotive engineer, Shell Oil Co.; R. M. Ladevich, senior project engineer, Standard Oil Co. of Indiana; Gordon C. Gregory, development engineer, Barber-Greene Co.; James M. Kirwin, project engineer, Bendix Products Division, Bendix Corp.; Chicago Section Membership Chairman O. F. Genz, sales representative, Garlock Packing Co.; W. R. Williams, assistant chief engineer for vacuum power, Bendix Products Division, Bendix Corp.; and National SAE Membership Chairman W. J. Lux, supervising engineer, Research Department, Caterpillar Tractor Co.

"Pilot Project" is the program, inaugurated by Membership Chairman Lux, designed to emphasize the personal approach in interesting qualified engineers for SAE membership. Results of "Pilot Project" work by all Sections will be coordinated through a Sections Membership Program Subcommittee of the Membership Committee. The Subcommittee is headed by Norman Mollinger, sales engineer, Ladish Co.

When a student walks along the University of Idaho's "Hello Walk" (above), it is a tradition for him to say hello to each person he meets.

SAE at University of Idaho

The Gothic-styled clock tower of the University of Idaho's Administration building lends atmosphere to the campus.

IDAHO, the famed "potato state," is also producing engineers . . . . and three-fourths of those graduating in 1960 were SAE Enrolled Students. With a Mechanical Engineering Department of about 200 enrolled students, the University of Idaho has a very active SAE Student Branch.

The Idaho Student Branch became an official part of SAE in April of 1951 through the efforts of Prof. Norman F. Hindle, past chairman of the college's Mechanical Engineering Department, and the department's current chairman, Prof. Henry W. Silha. The solid establishment of the young Branch was aided by the help of two active members of SAE Spokane-Intermountain Section, William A. Mast and John L. Peters. Faculty advisors for the Branch have been Prof. C. D. King and Prof. Silha. Prof. W. P. Barnes is the current advisor.

The Student Branch works closely with the Spokane-Intermountain Section, which invites the Idaho students to attend Section meeting throughout the year.

Early in May of each year, the Section sponsors a student paper contest, in which two of Idaho's students participated this past year. James Child entered the contest with his paper the new "Rotary Combustion Engine" and Robert Evans spoke on the "Addition of Tetraethyl Lead to Gasolines."

Aside from participation in Section activities, the students plan field trips and other activities independently. This past year, under the leadership of Student Chairman John T. Baker they visited the Recycle Test Reactor at

Hanford, Wash. and the Swimming Pool Research Nuclear Reactor at Pullman, Wash. They are currently making preparations for a local "Economy Run" which they plan to have in the fall. This project will be under the leadership of James C. Child, student chairman for 1960–1961.

SAE student effort coordinates with the University's belief that *application* of classroom theory is a major factor in the education of an automotive engineering student. The college mechanical engineering laboratory is supplied with both gasoline and diesel model engines and a 150 horsepower electric dynamometer. Three recent additions to the laboratory are a gas turbine test unit, a 150 psi two-stage air compressor and an axial-flow research fan unit.

The entire Engineering College is supplied with specialized laboratories for junior and senior engineering students, in addition to the conventional drafting rooms and science laboratories for the basic work of freshmen and sophomores. Besides the mechanical engineering laboratory, the school has a remodeled agricultural engineering laboratory with facilities for farm shop, farm building, and rural electrification instruction; a new hydraulic and irrigation laboratory; an electrical engineering laboratory equipped for work in power, electronics and radio; and a structural and materials testing laboratory used not only by the Idaho students but also by the Idaho Department of Highways and by engineers, architects, and construction agencies throughout the state and region.

The University's College of Engineering, which has about 800 enrolled students, offers standard four-year courses in Civil Engineering, Electrical Engineering, Mechanical Engineering with an aeronautical option, Chemical Engineering, and — in cooperation with the College of Agriculture — Agricultural Engineering.

Some engineering students find it advantageous to take five years to complete their course. The University encourages this method for those who desire it, as it allows the student more time to select electives from other departments and to participate in SAE and other student activities.

Among the SAE member-alumni of University of Idaho are: David R. Shoults, general manager, Aircraft Nuclear Propulsion Department, General Electric Co.; Stanley G. Thomas, design engineer, Convair Division, General Dynamics Corp.; Roger W. Gallagher, design engineer, Hyster Co.; Henry N. Ard, mechanical superintendent, Woods Operations, Potlach Forrests, Inc.; John A. Keller, technologist, Research Department, Socony Mobil Oil Co., Inc.; Joffre P. Myers, design engineer, Sandia Corp.; Melvin C. Taggart, design engineer, Thiokol Chemical Corp.; Paul Durning, 2nd Lt., U. S. Army, Chemical Corps.

WILLIAM P. BARNES, associate professor of mechanical engineering, to whom SAE Journal is indebted for the material for which this article was written, is Faculty Advisor to the SAE Student Branch at University of Idaho.

Barnes

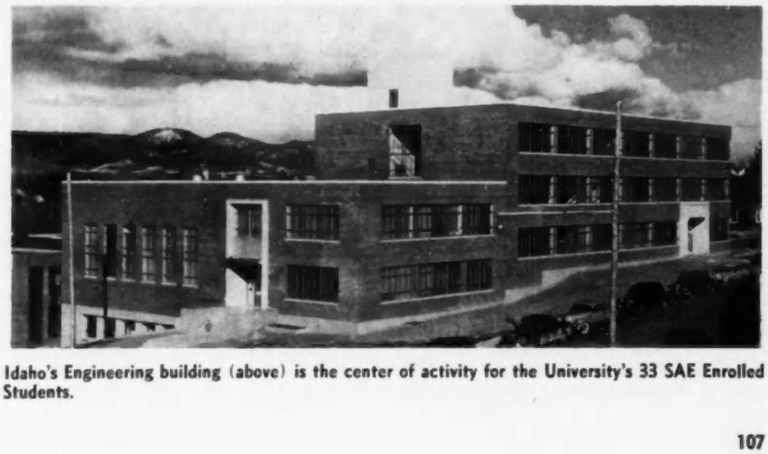
"We certainly do appreciate your willingness," he writes, "to show other people throughout the country that we have far more to sell here at Idaho than the famous 'potato'."

Barnes graduated from the University of Idaho in 1948 and was employed by the United States Department of Agriculture, for a year, as assistant engineer at Boise National Forest, Boise, Idaho. He received his Masters Degree from Yale University in 1950 and joined the University of Oklahoma as instructor of mechanical engineering.

From 1952 to 1954 he was mechanical engineer for the National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratories, Cleveland. In 1954 he became associate professor of mechanical engineering at University of Utah, and remained there until joining the staff of University of Idaho in 1958.

Barnes has been a member of SAE since 1950, and was chairman of Salt Lake City Section during the 1956–1957.

SAE students (left to right) Douglas Vanerka and Moyle Braithwaite run a performance test on a late model Diesel Engine, using a 150 horsepower Electric Dynamometer for power absorbtion.



Idaho's Engineering building (above) is the center of activity for the University's 33 SAE Enrolled Students.

SAE's CEP News

COOPERATIVE ENGINEERING PROGRAM

4 New Non-Destructive Test Methods

THE SAE IRON AND STEEL TECHNICAL COMMITTEE, which celebrates its golden anniversary this year, has come up with four new SAE Handbook reports on non-destructive test methods. Their issuance in the 1961 edition will mark several years of ISTC effort to provide industry with a basic understanding of what various non-destructive tests can do to maintain and improve the quality of ferrous and non-ferrous materials.

The four test methods described in the new SAE Information Reports pertain to ultrasonic, radiographic, eddy current, and liquid penetrant. And according to M. F. Valade, chairman of the originating ISTC Division 25 — Test Methods, a fifth test method on direct reading spectroscopy will be completed shortly.

Ultrasonic Inspection

This versatile test method facilitates detection . . . on surfaces and internally . . . of laps, seams, voids, cracks, bubbles, inclusions and the like. It is made possible by the characteristic of most solid materials to support the transmission of high frequency sound waves which vary for different materials and depend on a material's physical properties.

Since test frequencies are above the audible range (usually between 100 thousand and 25 million cycles per second), a liquid such as water or oil is used to couple the energy from the transducer to the material under test.

Two basic techniques . . . immersion and contact . . . are detailed in the report along with the three types of test: Pulse echo, through testing, and resonance testing. Advantages and disadvantages for each test type are also given.

Radiograph Test Method

This report supplies users with enough information to decide whether radiographic methods apply to a particular inspection problem. It does not, however, go into the massive detail currently available on the technical aspects of inspection radiography. A bibliography appended to the report has been provided to meet such needs.

Pertinent information on the selection of equipment and on protection from radiation are covered as well as the application of radiographic inspection of castings and weldments.

The report also describes how radiant energy in the form of X-ray and gamma rays is transmitted through test objects and recorded on film or observed directly by fluoroscopic methods.

Eddy Current Testing

Eddy currents, as described in this report, are introduced into the test object as a result of current flowing through a coil configuration. The coil configuration may assume a wide variety of shapes and arrangements . . . and may completely surround the part under test or simply be placed on or near the surface.

The character of the test object may then be studied by observing changes in amplitude and distribution changes. These changes are reflected in exciting or auxiliary coils so located as to be sensitive to the desired eddy current effects. They may be measured as voltage differences, current differences, or changes in the impedance of the coil or coils.

Liquid Penetrant Test Methods

Liquid penetrant tests are suitable for finding minute defects open to surfaces. Generally used for non-magnetic materials such as plastics and ceramics, they will detect cold shuts, seams, shrinkage, porosity, and cracks of all types that reach the surface of these and other materials.

Capillary action is the principle on which the test is based. When a liquid penetrant is applied to the surface for inspection by dipping, spraying or brushing, surface defects may be observed by the bleeding out of the penetrant after the excess liquid has been removed. This is done under black or white light, depending on the type of penetrant used . . . fluorescent or non-fluorescent.

SAE Gets Urgent Call for 40 Lbs of Dust

THE far-reaching effect of one SAE Recommended Practice was underscored recently by an urgent request which came to SAE Headquarters from Johannesburg, South Africa for 40 lbs of dust.

An air cleaner manufacturer, in trying to meet requirements imposed by the South African Bureau of Standards, found that his new product would have to meet test requirements specified in SAE's Air Cleaner Test Code before it could be marketed. Lack of the *kind* of dust described in the SAE report prompted the unusual request. (The dust is described both chemically and according to micron size in the SAE Handbook.)

Informal industry practice in the U. S. has been to obtain the dust through AC Spark Plug Division which gathers the dust at a GMC proving ground in Arizona and distributes it to industry.

One bemused SAE staff member commented that it would certainly set the air cleaner industry back if someone built a housing project over all that dust.

Diesel Engine Wear Defined in CRC Manual

Based on paper by

F. A. Robbins
Koppers Co., Inc.

L. G. Schneider
U. S. Naval Engineering Experiment Station

G. H. Shea
Socony Mobil Oil Co., Inc.

THE new CRC Diesel-Engine Rating Manual (No. 5) permits any laboratory to define in universally accepted terms those engine conditions significant to performance, life, reliability, and maintenance. From it, users may select rating techniques applicable to:

- Pistons (including rings).
- Cylinder liners and heads.
- Valves and valve gear.
- Oil system and air box deposits.
- Injection equipment.
- Engine Turbochargers.
- And such items as crankshafts, piston pins, filters, screens, and gearing.

The Manual defines conditions, but does not evaluate. This is a premise which evolved at the initial meeting of the CRC Rating Systems Panel held in May 1955, in Bartlesville, Okla. At subsequent meetings, it was decided that diesel-engine pistons could best be evaluated for lacquer deposits by utilizing an area demerit system and color gradations of brown and gray from clean to black. As a result, a brown scale and a gray scale of 10 graduations were established. By matching a lacquer deposit condition with either the brown or gray scale, compromising intermediate hues between the two scales to identify shade, a numerical color factor can be established. By using a nomograph, a demerit value for the surface may be established on a per cent area basis.

During the Panel's study of deposits in oil systems, various ways of evaluating thickness and texture were considered. It was finally decided that the scratch gage (developed by the CRC Engine Deposit Rating Panel) was suitable for diesel engines. A procedure for establishing a volume factor which furnishes a weighted interpretation of the deposit was created. Two thicknesses less than the minimum scratch gage thickness (1/128 in.) are recognized and identified as Thickness A and Thickness B. Total surface is rated by averaging the thickness of deposit on a per cent area basis by use of a graph. This rating is known as the "CRC Volume Factor," which in turn may be converted to a demerit rating by use of the nomograph.

Photographs are used extensively to illustrate conditions of valves, lifters, gears, wrist pins, and bearings. The "Album of Reference Photographs — Gear Tooth Condition," previously available as CRC Report 316, is also carried in the Manual.

To establish industry acceptability of techniques given in the Manual, six different laboratories conducted trial ratings. These tests took place from September 1958 through April 1959, and ultimately led to the Manual's approval for publication by the CRC — Diesel Committee.

To Order Paper No. 121B . . . from which material for this article was drawn, see p. 6.

Handbook Reports To Be Numbered

A NUMBERING system for all SAE Handbook reports is being studied by the *ground vehicle* Councils of the Technical Board as well as by the Councils' technical committees. Endorsed by the Technical Board at its June 9 meeting in Chicago, the proposed system will also affect TRs (Technical Reports of interest to special industry segments). It has the following features:

- A non-significant number will be assigned to each standard, recommended practice, or information report.
- The letters SAE will precede the number to identify the Society as the source of the report.
- Revision letters will follow the number to identify technical changes that might affect interchangeability or performance.
- The system will not be retroactive.
- Any further identification of an item or section within a given report would be added after the revision letter. However, the selection and use of such identification would be entirely at the discretion of the appropriate committee.
- The report number will be assigned at SAE Headquarters.
- Existing reports which already have numbers (mainly non-metallic materials) will arbitrarily retain their present designations.

Publication Policy Committee thinking behind these recommendations runs along the following lines: If a significant numbering system were used, it would break down almost before it began. Consequently, the non-significant system was selected as the simplest to administer.

The PPC also feels that the main purpose of report identification is to bring the engineer and report together. Consequently, internal identifications will be left to the discretion of originating or guardian committees.

News from SAE Technical Committees

LIGHTING COMMITTEE VOTES ON NEW REPORT — After nearly 2 years of study and discussion, the SAE Lighting Identification Code Subcommittee has completed work on a proposed SAE Recommended Practice which would provide lighting equipment manufacturers and suppliers with a uniform marking code to indicate the SAE Lighting Standard or Standards to which a device conforms. The Subcommittee, headed by Milton Jovanovich, Ford Motor Co., recently submitted the proposed code to letter ballot of the SAE Lighting Committee.

AUTOMOTIVE GLAZING — A section on how to specify dimensional tolerances for *curved* automotive safety glass parts has been added to the SAE Recommended Practice, Automotive Glazing. An essential requirement of this new section is reference to the automobile manufacturer's master die model when tolerances for size, thickness, and curvature are being sought. The revised report will appear in the 1961 SAE Handbook.

G. K. MANNING, Battelle Memorial Institute, will head the newest division in the Iron and Steel Technical Committee structure. Designated Division 36, Carbon Steel Hardenability, it will develop hardenability ranges for carbon steels.

CARL WALTON, Crucible Steel Co. of America, succeeds M. W. Dalrymple as chairman of ISTC Division 7 — Carbon Steels. Dalyrmple, who became chairman in 1956, was recently commended by the ISTC Executive Committee for his many services to the Division.

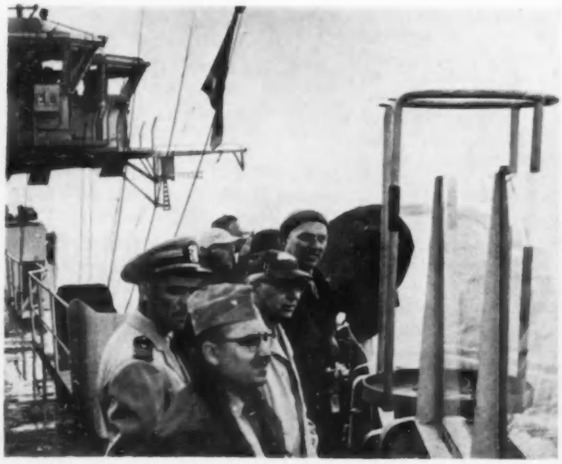
CHARLES N. MANN, General Motors Proving Ground, will succeed F. L. McRay, Allis-Chalmers Mfg. Co., as chairman of the Test Codes Subcommittee of the Construction and Industrial Machinery Technical Committee. Currently, the group is developing two codes: One applying to scraper loading ability, the other to vehicle cooling. Serving with Mann as co-chairman is **M. W. CLARK**, Caterpillar Tractor Co.

ON THE FLIGHT DECK of the U.S.S. Hancock are members of the two SAE Aero-Space Committees which met jointly to discuss standardization pertinent to aircraft undercarriages.

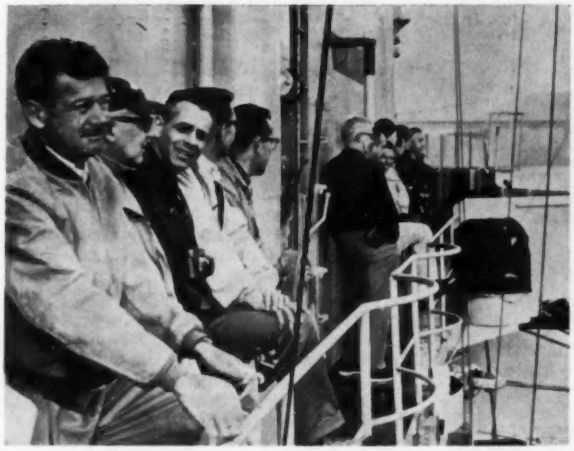
36 Seafaring Engineers Hold Parley Aboard Aircraft Carrier

LEAVING San Francisco's Golden Gate Bridge astern, 36 engineers spent five days aboard the U. S. aircraft carrier Hancock where problems unique to carrier-based planes were observed first-hand. The expedition consisted of members from two SAE Aero-Space Committees who held joint meetings aboard the carrier in May. The groups involved were SAE Committee A-5, Aircraft Wheels, Brakes, Skid Controls and Axles, and Committee A-12, Aircraft Landing Gear, Shock and Control Mechanisms.

At the meetings, standardization problems of interest to both Committees were discussed. Among the subjects broached were anti-skid equipment, parachute drag during rejected take-off, heat detection systems, landing impact and cable arrestor problems.



FROM BEHIND A WIND SHIELD members saw a jet catapulted into flight.



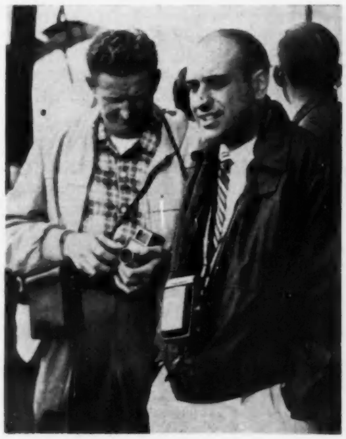
A DESTROYER ESCORT is refueled at sea while members watch from catwalk.

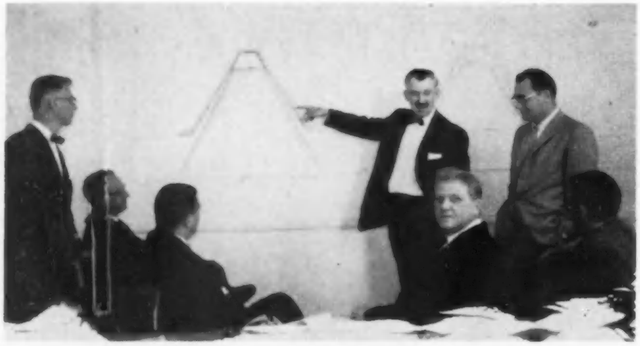
INFORMAL TALKS WITH THE CREW gave the group a better feel of operating problems.

COMMITTEE CHAIRMEN N. W. Maygar (A-12) and B. F. Jones (A-5) are shown topside between sessions.

ARRESTOR CABLES leading to an elaborate energy absorption system are used to decelerate landing aircraft.

PICTURE TAKING was popular before and after meetings.





EFFECTS OF HIGH TEMPERATURES (1200 F or above) on the new wider tolerances for lead and half angle error for screw threads specified in the A revision of MIL-S-7742 were examined during a 3-day meeting of SAE Committee E-21, General Standards for Aircraft Engines, in Kansas City, Mo. Viewing a 1000 : 1 scale drawing of a .250–28 thread form are from left: Chairman Lloyd Grodian, GE Flight Propulsion Division; J. A. Bishop, Wright Aeronautical Division; E. A. Brass, Lycoming Division; Donald Seidel, Westinghouse Electric Corp.; W. Aksomitas, Pratt & Whitney Aircraft; E-21 Vice Chairman T. L. Gray, Marquardt Corp.; and R. G. Larkin, GMC Allison Division.

New SAE Reports

. . . Scheduled for 1961 Handbook

AUTOMOTIVE TRANSMISSION DIAGRAMS . . . Automotive transmission arrangements are illustrated in this new SAE Recommended Practice by means of a series of schematic diagrams. They were developed by the SAE Transmission Committee in an effort to standardize existing practice and to promote an understanding of the functional relationships of various transmission components.

TIRE SELECTION TABLES FOR AGRICULTURAL MACHINES OF FUTURE DESIGN — Use of the tables contained in this report will minimize the number of tire sizes used on agricultural machines. It will also improve standardization by providing a series of tire sizes designed to be used with a common wheel. The SAE Tractor Technical Committee developed this new Recommended Practice.

BATTERY IDENTIFICATION SELECTION CHART — A ready means of establishing SAE group numbers for new batteries as they are developed may be found in this new Information Report. Its approval means that SAE group numbers may be assigned on a *physical dimensions* basis to new battery types without Automotive Council approval in each instance as was previous practice. The Automotive Council will, however, continue to review the electrical requirements applicable to new batteries. This report will appear in the 1961 Handbook as well as in TR 33, Electrical Equipment, which will be issued this month.

EXHAUST FLANGES FOR INDUSTRIAL ENGINES — Standardization of engine exhaust flanges will eventually lead to standardization of engine outlets. This is what the Construction and Industrial Machinery Technical Committee hopes to achieve by providing an SAE Recommended Practice. Such standardization will permit interchangeability of optional engines in pieces of OEM equipment without extensive modifications to the exhaust system.

SPECIFICATIONS FOR INDUSTRIAL TRACTOR FRONT-END SHOVEL AND LOADER — To define components for specification writers is the aim of this Standard. In addition, it provides a common language for engineers who design, build, and service this type of equipment. The report was developed by the SAE Construction and Industrial Machinery Technical Committee.

WAGON NOMENCLATURE — Common terminology for wagon parts and components is given in this new SAE Standard which will supplement five other existing nomenclature reports also developed by the Construction and Industrial Machinery Technical Committee.

48 Hours Cut from Compression Set Tests

Based on committee presentation by

W. H. King

Acushnet Process Co.

TEST labs will get a boost in production when compression set test times are cut from 70 to 22 hr. This drastic reduction was made possible by extensive investigations which show a direct correlation between results at the two test times for the wide variety of elastomeric compounds described in the SAE Standard, Specifications for Elastomer Compounds for Automotive Applications (SAE 10R-ASTM D735). Coupled with the new time is a rise in test temperature from 158 to 212 F.

Prior to the establishment of the new test time, members of the ASTM-SAE Technical Committee on Automotive Rubber ran tests on many production compounds, including those shown below. The results confirmed that between the two test times, a near constant ratio of two-thirds exists for compression set values.

General Purpose Neoprene Compounds — SC315, SC415, SC515, SC615, SC715, SC815, and SC915.

Low Set Neoprene Compounds — SC315B, SC415B, SC515B, SC615, SC715, SC815, and SC915.

General Purpose Nitrile Compounds — SB315, SB415, SB515, SB615, SB715, SB815, and SB915.

Low Set Nitrile Compounds — SB315B, SB415B, SB515B, SB615B, SB715B, SB815B, and SB915B.

For simplification purposes, the exploratory tests were run only on compounds in the tensile category of 1500 psi. Tests were conducted for 22 hr at 158 F, and for 22 and 70 hr at 212 F.

To assume realistic values, the TCAR extended its experience with the new requirements by asking fabricators to review *all* of their production compounds in *all* tensile categories. This study showed that the 22-hr test was a satisfactory replacement for the 70-hr test since material that passed the old 70-hr test also passed the 22-hr test, and a failure in one test also meant a failure in the other.

The shortening of test time is significant because of the part compression set tests play in determining and controlling state of cure. Intended to measure the ability of rubber compounds to retain elastic properties during prolonged action of compressive stresses, they produce data which can be correlated with actual service.

The new standards have been incorporated into tables appearing in the 1959 Supplement of the Book of ASTM Standards as well as the 1962 SAE Handbook.

Briefs of SAE PAPERS

continued from p. 6

uration shown; power package best suited for airship propulsion would combine compact-core reactor as heat source with open "Brayton" cycle turboprop engines for power conversion; unit type shield considered best suited to airship.

Potential of Nuclear-Powered Aircraft for Commercial Cargo Transport, J. F. BRADY. Paper No. 169B. Typical commercial nuclear powered aircraft might weight approximately 1,000,000 lb, have length of about 300 ft, wingspread of some 300 ft, and be capable of carrying various nuclear aircraft systems and their relative systems.

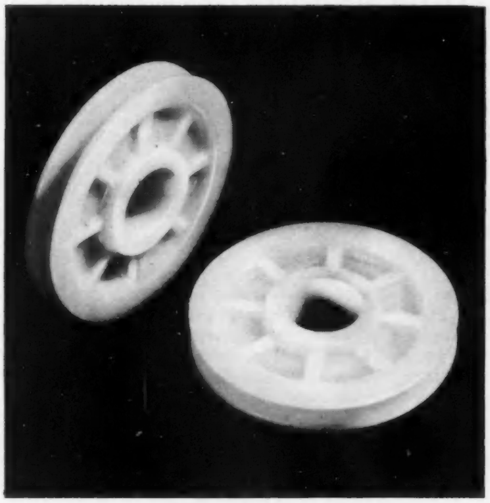
Flight Reliability in Nuclear Aircraft, L. W. CREDIT. Paper No. 169C. Propulsion system reliability as related to safety of flight; valid reliability experience for chemical aircraft is assumed to determine design goals for equal reliability in nuclear craft; flight reliability approaches for (1) single reactor with redundancy in all systems outside reactor, and (2) dual reactors, plus redundancy in systems outside reactor; effect on aircraft design.

Trends in Navy Turboprop/Turboshaft Engine Developments, A. L. RASMUSSEN. Paper No. 170A. Naval missions require aircraft of moderate speeds operating at moderate altitudes; this indicates continuing need for shaft-power turbine engines; significant variations, combinations, and configurations available in engines under development in rage of shaft horsepowers from about 50 to 16,000; problem areas include component compatibility, reduction gearbox reliability, torquemeter adequacy, droop, and propellers.

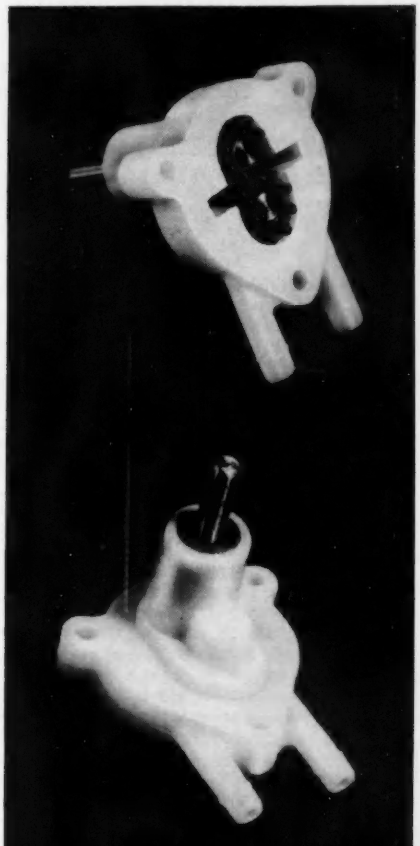
Canadair 44 — Breakthrough Cargo Aircraft, K. H. LARSSON. Paper No. 170B. CL-44 has been completely redesigned and embodies United States materials, standards, processes and equipment; increases in design weights and fuselage volume, installation of Tyne engines and other major modifications; advantages of turboprop engines; direct and indirect operating costs given; air compatibility; effect of mechanical loading on utilization and operating cost.

Performance and Design Criteria of Adaptive Circuit Proposed for Space Re-Entry Vehicle, W. BEAUCHEMIN. Paper No. 171A. Theoretical analysis shows how aerodynamic and structural

continued on p. 116



Long-wearing parking-brake cable pulleys of DELRIN are being used by a leading car manufacturer. The full radius groove in DELRIN provides natural mating, maximum contact area with the cable . . . eliminates the cable pinching caused by split-type steel pulleys. Pulleys have been tested under severe long-term conditions of high load and temperatures.



A unique design of a windshield washer pump body is being produced in DELRIN offering exceptional corrosion resistance, strength, stiffness and dimensional stability at elevated temperatures. Housing of DELRIN is easily molded to meet the close tolerences required. (By The Delman Company, Cookeville, Tennessee.)

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Briefs of SAE PAPERS

continued from p. 113

bending characteristics of vehicle establish design criteria and requirements and affect choice of adaptive circuit for automatic flight control system; circuit described includes linear gain-changing element which maintains rate loop of flight control system at its neutrally stable point; mathematical model of circuit loop is derived.

Minimum Flyable Handling Qualities of Airplanes, G. BULL. Paper No. 171B. Report of investigation to establish minimum longitudinal handling qualities required for returning airplane to its base in emergency in case of failure of stability augmentation equipment; results of flight tests using three different pilots show that pilot can successfully operate very unstable aircraft, at least for limited periods.

Landing Aircraft Automatically and Reliably, E. W. VELANDER. Paper No. 171C. New approach to flare computation problem; formulation of system that closely approaches prediction type of control used by human pilot; prediction equations were developed for control of terminal conditions of aircraft for landing flare; investigations of typical landings have revealed that most satisfactory landings are at sinking rate of 2 ft or less per sec.

Discussion of Some Design Problems Associated with Artificial Feel Systems of Airplanes with Irreversible Powered Flight Controls, T. Y. FENG, D. C. NEIL. Paper No. 171D. Basic study of longitudinal stick free static and dynamic stability; in stick free static stability, trim reversal was eliminated by Mach compensation device which improved characteristics of stick force speed stability; in stick free dynamic analysis, most satisfactory system comprised Q-bellows with Mach and dynamic pressure compensation devices, very light centering springs, low stick friction and no bob weight.

Considerations of Rendezvous Problems for Space Vehicles, J. C. HOUBOLT. Paper No. 175A. Problems involved in transfer of personnel or supplies from ferry vehicle to space station; injection, approach, terminal and acquisition phases; penalties due to errors in velocity, altitude, orbital inclination, etc., and schemes for correcting flight paths so as to use minimum of fuel; wait periods of many days appear necessary if launch is to be made into correct orbital plane, but only one day or two if launch is made into incorrect plane with subsequent correction.

Adaptive Control Considerations for Re-entry Flight, J. W. CLARK, J. H. AHLBERG. Paper No. 175B. Series of maneuvers which are required to land manned space vehicle at predesignated airfield on earth; objectives of maneuvers, types of control and stabilization systems which can be used in each external environment, and sources of moments which disturb orientation of vehicle are discussed.

X-15 — a Reaction Control Aircraft, GEORGE B. MERRICK. Paper No. S-247. Development of X-15 plane is described, with particular emphasis on reaction control system. The performance profiles of other aircraft are compared with that of X-15. It appears that the X-15 will extend current altitude capabilities of manned vehicles by a factor of four and double the speeds obtained to date. To accomplish this, the X-15 uses to the fullest extent the

pilot's capabilities for control and proved concepts in its control systems.

Scheduling and Dispatching of Airline Aircraft, T. M. PLUNKETT. Paper No. S-256. Outlines how United Air Lines provides for proper scheduling of aircraft. Covers development of method that permits actual simulation of each proposed flight under a given set of circumstances. This is accomplished by use of Bendix G-15 digital computer, which produces and "costs out" accurate flight plans in a fraction of time required by hand method.

FUELS & LUBRICANTS

Motor Oil Classification — or Confusion, A. D. BONNINGTON. Paper No. S-251. Problem of motor oil classification is reviewed and API Service Classification is explained. MS test sequences are described and evaluated.

GROUND VEHICLES

Characteritics of Diesel Engine for Light Truck and Taxicab Applications, HEINZ HOFFMAN. Paper No. S-250. Reviews present status of small 4-stroke-cycle diesels in production for passenger cars; and development and production status of Mercedes-Benz OM 621 diesel engine (used on 190D); description of engine.

Drive Trains for Agricultural, Industrial, and Construction Machinery Equipment, JAMES A. MILLER. Paper No. S-252. A study of the trends and requirements of transmissions to suit the varied needs of equipment is presented.

Fuel Cell Powerplant for Electrically Propelled Earthmoving Machinery, HARRY K. IHRIG. Paper No. S-253. The installation of a commercial-sized fuel cell to a regular D-12 farm tractor chassis is described briefly.

Twelve-Foot High Signatures in Diesel Smoke, QUENTIN B. JERVIS. Paper No. S-254. Tells of program undertaken by Silver Power Diesel Fuel Injection Service covering research on injector operation and development of a procedure for repair. Discusses problems, manufacturing processes used to correct them, results achieved by injector repair, and details instructions to mechanics on installation and timing.

Evaluating the Compact Car, LAURENCE E. CROOKS. Paper No. S-255. Discusses what is a compact car and how it can be evaluated, with emphasis on riding qualities, power-economy relationship, and bodies.

Dodge Truck Heavy-Duty V-8 Engines, H. L. WELCH and R. S. RAREY. Paper No. S-257. Describes new family of V-8 gasoline engines produced by Dodge for the heavy-duty trucking industry. Covers: basic objectives, background that influenced the design, description of engines, and results obtained.

PRODUCTION

Applications and Limitations of Metal Removal Techniques in Aircraft and Missile Manufacturing, M. FIELD. Paper No. 160A. In aircraft manufacturing, milling is most widely used operation, followed in importance by drilling and tapping; in missile manufacturing major operation is turning, followed by drilling, milling, tapping and grinding; tabulation of aircraft and missile alloys divided into eight groups; non-machining methods of metal removal.

Applications and Limitations of New Developments in Metals Joining Processes, P. J. RIEPPEL. SP-173. Review, compiled by Battelle Memorial Inst., of new developments; fusion welding, resistance welding, brazing, solid state bonding processes, and cutting and coating; developments of each group; introduction of plasma jet as heat source has supplied new tool for

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Briefs of SAE PAPERS

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use in cutting and coating applications. 60 refs.

Production Application of High Energy Rate, E. W. FEDDERSEN. Paper No. 160C. Three methods of applying high energy rate to deformation of materials are explosive, hydroelectric, and pneumatic-mechanical; applications of explosive forming in aircraft, missile, and engine accessory fields; shapes considered; high energy spark unit developed by Convair-General Dynamics Corp.; sequence of operations by hydroelectric process; "Dynapak" pneumatic-mechanical machine which releases stored h-p nitrogen gas to accelerate piston to high velocity thus developing high energy rate forming process; examples.

Process Refractometer for Continuous Plant Stream Monitoring, D. D. DORAN, Y. M. CHEN. Paper No. 161A. Principles for measuring refractive index are reviewed; development of Electronic Indexometer by Daystrom, West Englewood, N. J., its operating principle and temperature compensation; unique electronic calculation circuit is designed to simulate scanning light ray phase shift as it scans past critical angle; this is definite advantage for rechecking calibration and standardizing overall measuring circuit; schematics and block diagram.

These digests are provided by ENGINEERING INDEX, which each year abstracts 30,000 engineering articles from 1500 different publications and classifies them into 249 "fields of engineering interest."

To order the SAE papers digested here, circle the numbers in the "Readers Information Service" blank on p. 6 corresponding to the numbers appearing after the titles of the digests of the papers you want.

ALSO AVAILABLE

1960 SAE NATIONAL PRODUCTION MEETING . . . SP-330 consists of 11 panels, as follows:

Standards for Control, reported by R. W. McDONALD, secretary. Lists steps to be taken by a time study analyst in preparing for a study, discusses training of time study engineers, advantages and disadvantages of time study. Notes that predetermined standards permit establishment of the correct methods pattern at the time the standard is being developed. Discusses briefly "work sampling" as a measurement technique for the quantitative analysis in terms of time, of the activity of men or machines or of any observable state or condition of operation.

Materials Handling for Low Cost Production, reported by EDWARD J. HAYES, secretary. Says that modern analytical techniques can be of great help in solving materials handling problems. Stresses need for better packaging, loading, transporting and unloading between end of vendor's manufacturing line and the beginning of the user's. Discusses selection of materials handling equipment. Suggest not designing too elaborate a sys-

tem, because conditions may change.

Product Evaluation for Cost Reduction, reported by J. A. CHANTRY, secretary. Discusses Operations Research — application of the scientific method to operational problems . . . also application of Value Analysis, followed by a system for organized project study.

High Energy Forming reported by STANLEY PETERSEN, secretary. Discusses forming, forging, metal hardening, metal welding, and bonding with explosives. Specific applications are mentioned.

Industry Takes a Second Look at Quality Control, reported by J. E. MEYERS, secretary. Quality control is one of the most challenging problems in the automotive industry. Complexity of design, major design changes, and growing customer discrimination increase its importance and it cannot be ignored in the face of mounting competition from abroad. Tells how to evaluate product quality, how to pinpoint trouble sources, and the use of specific quality standards.

Numerical Control of Machines and Processes, reported by R. C. MILLER, secretary. Numerical control of machines and processes is destined to have a tremendous impact on future manufacturing organization and operations. Discusses the need for re-orientation of procedures, and in some cases of organization, in order to implement engineering, tooling, and process planning under this new concept.

Manufacturing Expense Control, reported by H. J. FOEHRINGER, secretary. Industrial engineering, accounting, finance, and manufacturing management all have a keen interest in design and use of expense control reporting. Report integrates manufacturing expense control from these various viewpoints.

Late Developments in Manufacturing Processes, reported by ROBERT F. HUBER, secretary. Progressive manufacturing management must keep abreast of what's new in manufacturing knowledge. Discusses the latest in cutting tools, heavy press forging, metal finishing, and electro-chemical milling.

Management Development for a Manufacturing Organization, reported by B. E. ASCHENBRENNER, secretary. Selection, training, proper placement, and advancement of management personnel is an important key to organizational success. Actual training programs are described.

Futures in Cold Extrusion, reported by R. W. PERRY, secretary. The concept of taking a given quantity of metal and molding it cold into an accurate usable shape is growing rapidly in industry. Using as examples some of the accomplishments to date, the panel discusses the advantages to be gained by cold extrusion; and give their projections of its future in the manufacture of small parts, automotive, and military items.

Automation in the Job Shop, reported by L. B. MUSSER, secretary. Job shop operations present unique problems for application of automation practices. Machining, part planning and processing, production control, and administrative control are discussed as to their role in automation of the job shop.

To order SP-331, see order blank on p. 6.

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B.F.Goodrich Hi-Torque brakes are now available in seven basic sizes, from 17¼" x 4" to 26" x 7", with a variety of mounting designs. Brake actuation can be provided by either air-over-hydraulic, or direct hydraulic power. Thus you can use these brakes in your vehicles with a minimum of design change.

Hi-Torque brakes are now supplied as original equipment on a wide range of heavyweight vehicles: big dump trucks, tractor-scrapers, coal haulers, mine trucks, and other special vehicles. They provide up to 125,000 foot pounds of braking torque per brake in a smaller sized "package" than any other brakes. Hi-Torque brakes cut stopping distance approximately in half, compared to conventional two-shoe brakes tested on identical vehicles and loads.

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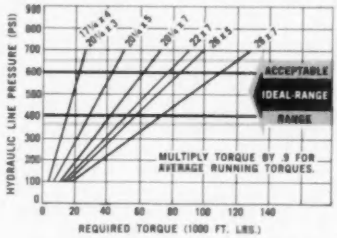

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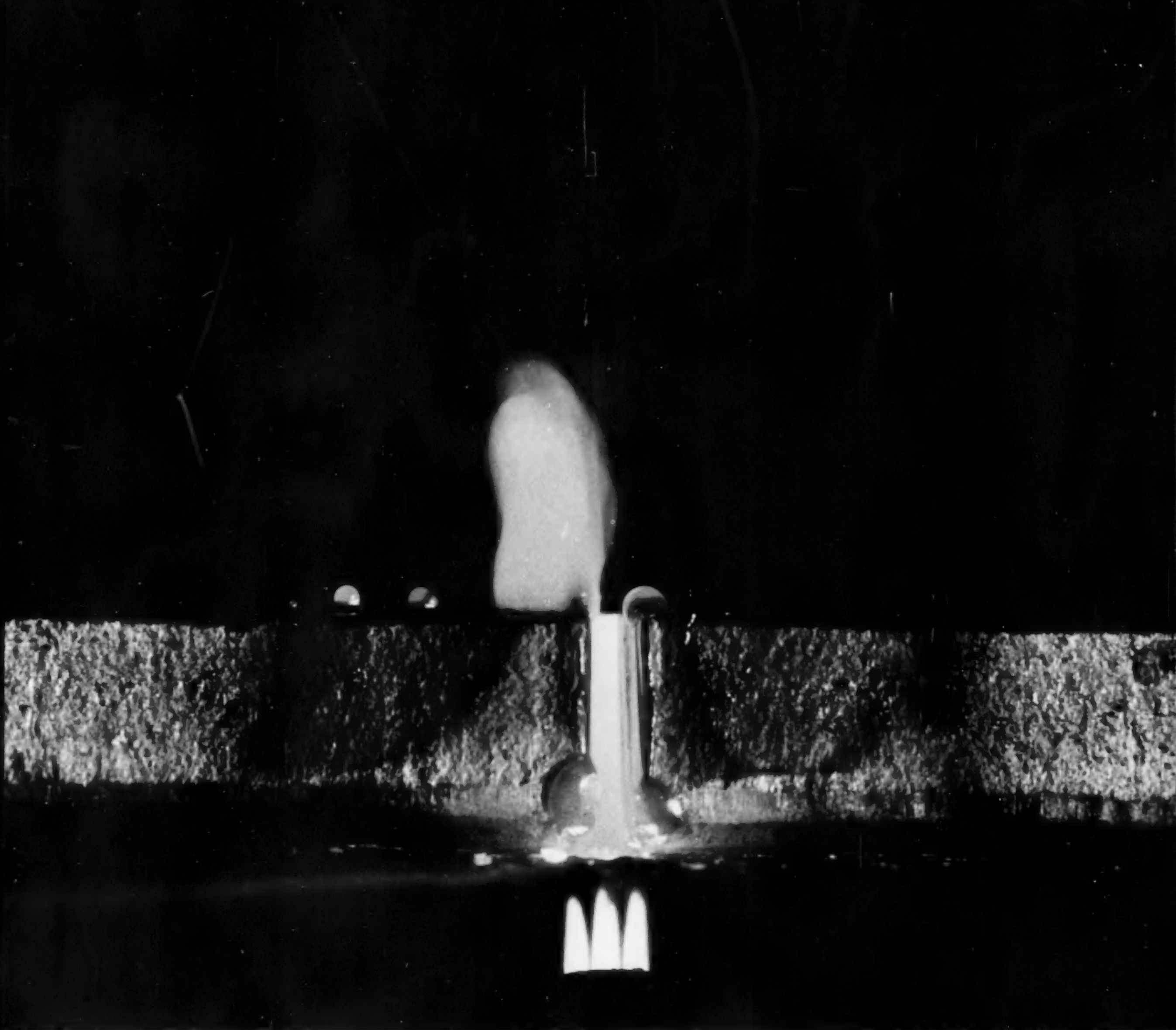

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Cutting Tool Trends

. . . continued from p. 91

As a finish turning tool for uninterrupted cuts at higher speeds. (2) For hard materials that resist cutting by other tool materials. (3) For abrasive materials, such as cast iron, where the high wear resistance of ceramics becomes important. (4) For machining materials with hardnesses of 40 Rockwell C, or higher, on which turning has replaced grinding in many cases.

The chief advantage of the super high-speed steels, such as the T-15 and M-4 types which include high quantities of vanadium and cobalt, is their potential for a greatly increased number of pieces machined per tool grind. Another plus is that cutting speeds can be boosted on many jobs. The new materials offer 2–6 times as many parts per grind as standard materials operated at the same speed. On the other hand, speeds can be increased by as much as 50% with the newer types of high-speed steels with the same number of pieces per grind as the older types of cutting tools. Tool life increases of 50% or more have been credited to a process that deposits tungsten carbide in the high wear areas of high-speed steel tools.

Cutters made of the titanium carbides offer the possibility of faster cutting speeds, and they have greater impact strength than the ceramic tools. A new grade, for example, has 64% titanium carbide bonded with nickel or molybdenum. It can cut in the range of 1000 sfpm and is competitive with ceramics. Another grade with 80% titanium carbide is about six times as wear resistant as competitive ceramics.

Serving on the panel Late Developments in Manufacturing Processes, in addition to the panel secretary, were: chairman: **Anderson Ashburn**, McGraw-Hill Publishing Co.; **R. Hook**, Warner & Swasey Co.; **A. Favre**, Aluminum Co. of America; **A. Zimmerman**, Acme Mfg. Co.; and **Arthur Watson**, Cleveland Pneumatic Tool Co.

(This article is based on a report of one of 11 panels on production subjects. All 11 are available as a package as SP-330. See order blank on p. 6.)

Quality Control Demands Top Billing

Based on report by secretary

J. E. MEYERS

International Harvester Co.

QUALITY control is one of the most challenging problems in the automotive industry. Complexity of design, major design changes, and grow-

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ing customer discrimination increases its importance and it cannot be ignored in the face of mounting competition from abroad.

While quality is largely a matter of personal opinion and opinions vary, the end point is the requirement of customers. At the same time, customers have no accurate method for expressing these requirements, so that becomes a problem itself. One solution is to approach it negatively, that is, find out what repairs have had to be made to a product at the customer's request. That's a specific reaction indicating customer dissatisfaction shorn of emotions and opinions, and it is a good way to evaluate product quality.

To help pinpoint the source of trouble, one company records dealer repairs to a sample of cars produced each month by each assembly plant. Such a record is kept for 12 months. The reports are analyzed and the results given to management. Once the problem is identified, corrective action must follow. This is vital. Unless responsibility for corrective action is assigned, nothing is accomplished and quality control becomes a mere data collecting agency.

Quality standards should be specific wherever possible. It isn't enough to say "must be smooth" or "must be flat." There should be a definite engineering standard specifying degree. Quality control means quality conformance to known specifications.

(Serving on the panel which developed the information in this article, in addition to the secretary, were Marlin Fuller, International Harvester Co. (chairman); Ray Celletti, International Harvester Co.; Dale A. Cue, Hoover Ball & Bearing Co.; and F. J. Newton, Ford Motor Co.)

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(This article is based on a report of one of 1 panels on production subjects. All 11 are available as a package as **SP-330. See order blank on p. 6.**)

Why Not Use Engine Oil in Transmission?

Based on paper by

ROBERT E. FLETCHER
Dana Corp.

GRANTED the nuisance of using different lubricants for engine, transmission, and axle, a common lubricant cannot be best for each unit. Therefore, if thought wise to eliminate a separate lube for the transmission, it would be better to develop a lube common to transmission and engine than one for the transmission and axle.

A common lube for transmission and engine would provide very satisfactory

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lubrication for the transmission, with the added advantage of lowering operating temperatures because of lower viscosity, and a longer drain period by virtue of the stability of engine oils.

It's been Tried and It Works

Engine oils have been used in transmissions for many years in a great number of fleet vehicles, and they have been satisfactory. Most engine oils being used are in the viscosity range of SAE 50, but there is considerable experience to show that lighter oils will suffice. One large bus fleet operator has used SAE 30 and SAE 10 engine oils in transmissions for years. In straight mechanical boxes the SAE 30 is used. The SAE 10 is used when mechanical transmissions are combined with a converter or coupling and a common oil supply between the two units was required. Minor design modifications were found necessary to permit using the SAE 10 engine oil, but these have been more than offset by the advantages.

To Order Paper No. 192B . . . from which material for this article was drawn, see p. 6.

CU Test Data Rate Compact Performance

Based on paper by

LAURENCE E. CROOKS

Consumers Union

Presented before SAE Williamsport Group

GOOD STEERING and handling are easier to achieve in the size and weight ranges of the compact cars. But all compacts don't handle equally well.

Location of engine and driving-wheels is but one item in fitting the compact car to the job expected of it. For hilly terrain in bad-traction weather, the rear-engined car is best for getting up, or through. At high speed on windy plains or parkways, it is advantageous to have the weight and driving wheels at the front, to give superior cross-wind behavior. . . . The conventional front-engine, rear-drive car is hard to beat where the demand is for maximum passenger space for a given silhouette (provided you can avoid running the driveshaft through the upholstery), maximum trunk space, and superior riding qualities.

One advantage of the rear-engined car, Consumer Reports tests indicate, is its light steering. It has "steering eagerness," as against what might be characterized as "steering reluctance" among the 8-cyl compacts.

What the compacts offer in riding comfort is, on balance, pretty acceptable . . . and Consumers Unions' "human integrating computers" have memories running back a hundred cars or so — from flea-like foreign small cars to the best-riding U. S. vehicles.

There is, among the new compacts, one old-fashioned, bouncy ride; one that is a little over-firm and one with drawbacks resulting from unconventional weight distribution. But we may conclude, for the conventionally laid-out cars, the compact-car handicaps of light weight and small size are surmountable to such an extent that a comfortable ride can be provided.

In judging riding qualities, two items must be recognized:

- Each person has his own predilections in riding qualities as in other matters.
- It is extraordinary what happens to a rider (as regards his reactions to a seat cushion) in the second or third hundred miles. He may, by that time, feel like swapping over-bouyant float for steady jar . . . or jar for float!

Mileage and Performance

Gasoline mileage and economy figures — to be properly interpreted —

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must be correlated with performance. The more of one, the less of the other.

Consumers Union tests, made on a U. S. highway a few feet short of a mile long and with a constant grade of slightly better than 9%, show:

On this grade, the terminal speed of the V-8 sedans runs from 60 to 75 mph. Terminal for the compacts, as a group, runs from 45 to 55 mph. The "full-sized" 6-cyl cars are in about the same range. The small, Volkswagon-type vehicles end up between 35 and 40 mph.

Calculating mileage at 50 mph constant speed, Consumers Union tests show: a target figure for the big cars (but not too easily attained), 20 mpg . . . for the compacts (without too much attention to transmission equipment, but without overdrives), 25 mpg . . . for the truly small cars, 40 mpg.

To Order Paper No. S255 . . . from which material for this article was drawn, see p. 6.

Planning for New Product Introduction

Based on report by secretary
G. W. PERIMAN
North American Aviation

WHILE facilities planning and introduction of new products are interdependent, they are individual entities and should be recognized as such. The planning must be comprehensive in this age of rapid technological change.

Most companies place the responsibility for facilities planning on industrial or manufacturing engineering. And the trend is toward committee operation with an operating vice-president or equivalent among the group. The committee member affords a wider base of information for study and analysis than the "one man show." In the planning of such facilities, a return on capital investment of 25–35% is used as a goal.

The main objective in new products ventures is a low risk potential and high payout. Failures in such ventures range from a low of 37% to a high of 72%. Most companies have a new products department for the screening of ideas, and final decision is left to top management. In a small operation, screening may be done by the owner, president, and one or two top men.

Serving on the panel which developed the information in this article, in addition to the secretary, were: G. S. Mead, North American Aviation (chairman); J. A. Clark, Curtiss-Wright; E. G. Gleason, BuWeps, USN; C. W. Gold-

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beck, Thompson Ramo Wooldridge; C. A. Kalman, Booz, Allen & Hamilton; Lt. Col. F. J. Karlin, AMC Ballistic Missiles Center, USAF; H. F. Marx, Temco Aircraft; P. W. Norris, American Brake Shoe; and V. D. Sanford, North American Aviation.

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(This article is based on a report of one of four panels on aircraft production subjects. All four are available as a package as **SP-331. See order blank on p. 6.**)

Fleet Tires Yield Facts on Cord Fatigue

Based on paper by

W. G. Klein, M. M. Platt, and W. J. Hamburger

Fabric Research Laboratories, Inc.

TIRE cords in general do not become progressively weaker until failure. They fail suddenly. The failure is not associated with a degradation of fiber tensile properties and, moreover, localized bond failure is frequently, if not always, associated with such cord failure.

A study of cord fatigue in tires taken from a New York taxi fleet has shown cords adjacent to the failure to be of normal strength. After an initial, relatively rapid loss of cord strength there follows a long period in which the rate of loss is very small. The fiber tensile properties degrade at a very low rate; large losses in cord strength are attributable to fiber breakage at discrete points.

It was also found that fiber breakage appears to occur primarily in the flex zone and at filling yarn cross-overs. It seems to follow the helical line of contact between the two singles in the cord.

Significant local rubber damage (cord-rubber separation) appears to accompany large cord damage. Apparently, local bond failure gives rise to excessive local fiber strains, leading to early failure.

It was impossible to establish differences between Tyrex viscose and nylon in fatigue since the number of failures was small and all occurred at high mileage. Similarly, rates of degradation of tensile strength of cords containing either type of fiber could not be distinguished from each other.

To Order Paper No. 200B . . . from which material for this article, was drawn, see p. 6.

Why American Cars Are Built As They Are

Based on paper* by

HENRY LOWE BROWNBACK

Consultant

THE DESIGN of a car is influenced by conditions in the country of its manufacture. In the USA, the high level of income, cheap fuel, and easy credit make possible the purchase of the large cars demanded and often needed by the majority of American families and often bought as an article of prestige as well as utility.

Traffic in America is dense and fast moving. Therefore, high power is needed to pass at cruising speeds and for fast acceleration at low speeds, as well as for the operation of labor-sav-

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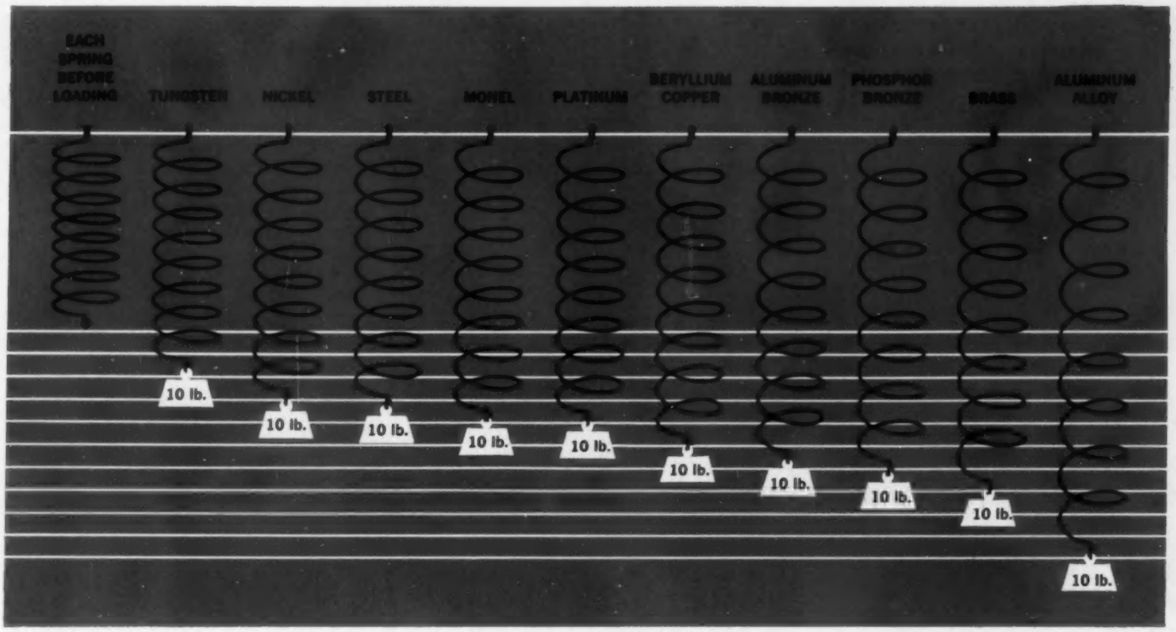
* The paper from which the material for this article was drawn was presented at the 8th International Automobile Technical Congress at The Hague. The Congress is sponsored by Federation Internationale des Societes d'Ingenieurs des Techniques de l'Automobile (FISITA).



How much deflection do you want in a spring?

The wide range of stiffness characteristics available in different materials offer unusual opportunity to solve spring deflection problems. How wide is shown in the chart above. The tension springs are all of identical dimensions but of different materials and indicate the relative deflection obtained from applying the same load (assuming the stresses are within safe limits). This basic principle is often overlooked in the approach to spring selection not only of extension springs but other types: flat, torsion, etc. Because our daily work includes such a wide range of spring usage, we are in a position to help you in the early stages of spring consideration, both in material selection and production short cuts. A handy pamphlet to have at your elbow is our "Metal Selector." Write for your copy.

5806

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Seaboard Pacific Division, Gardena, Calif.
Canadian Subsidiary: Wallace Barnes Co., Ltd., Hamilton, Ont. and Montreal, Que. Puerto Rican Subsidiary: Associated Spring of Puerto Rico, Inc., Carolina, P.R.

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ing accessories, which are needed on heavy cars when women are the drivers.

Criticism Poorly Based

Criticism has been leveled at the modern American car and if it is explored one can see why the average vehicle is what it is. Size, for instance, has come under fire, but large size is a requirement. Many families take long trips with much luggage and even with large trunk capacity there is often not enough room and the station wagon must be used to get necessary carrying capacity. Many families tow boats or house trailers over rugged terrain for long distances and this requires a robust, heavy car with reserve power.

The so-called power race has been criticized. Engineers did not invent the power race; they simply calculated the power necessary to handle the new type of car properly under prevailing conditions. The high-powered engines now used have been made practical by advances in materials, fuels, and engine design.

The American car was never designed to get the greatest possible power from a liter of piston displacement, nor the highest possible road speed, nor to corner in a four-wheel slip. It is a mass-produced article of commerce, just like the good old alarm clock, which gives good service to 89% of the American car buyers and can be kept on the road by indifferent mechanics.

Producers Are on the Ball

The big American companies are not eager to leap into new techniques, but you may be certain that they have them running in prototype form. And if they are not adopted, it might be well to study why this is so before trying to send new, untried things to the USA.

Time and Cost Cut in Fleet Washing

Based on paper by

R. L. FISKE
General Industries Division,
Oakite Products, Inc.

DIRT on transportation equipment is not just dirt. It's a mixture of many things, such as dust, ash, grit, film from exhaust fumes, oil, grease, bugs, film from hard water, and oxidation products. Any or all of these must yield to the detergent material used in washing.

To be satisfactory, a detergent must:

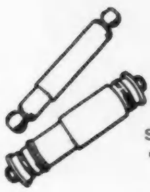
- Wet out and penetrate the soil.
- Keep soils in suspension so that they do not redeposit on the surface.
- Leave paint and aluminum alone, or be nearly neutral in pH.
- Sequester or chelate lime.
- Rinse freely and not spot or streak.
- Be effective in cold water; be safe and economical.

Cleaning compounds can be powered or liquid and most of them can be used in any of the available cleaning devices, although some might tend to produce too much foam in certain spray applications.

Devices for washing have kept pace with progress in cleaning compounds. Equipment ranges from units using air pressure to produce a lather or spray to those which operate like a spray washing machine, complete with brushes, a variety of nozzles, and pumps to deliver the solution to the nozzles.

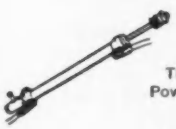
To Order Paper No. 204A . . . from which material for this article was drawn, see p. 6.

Load-Levelers* by Monroe Prevent "Tail  Drag"



MONRO-MATIC SHOCK ABSORBERS

Standard on more makes of cars than any other brand.



DIRECT ACTION POWER STEERING

The only truly direct-action Power Steering units available.

MONROE SWAY BARS

Specified as standard equipment on 15 makes of passenger cars.

E-Z RIDE TRACTOR SEATS

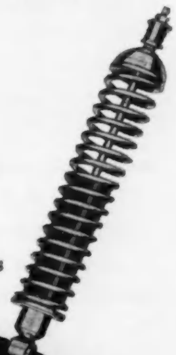
Standard on more tractors than all other seats of its kind combined.

Prevent bumping on driveways **and all the other problems caused by overloading today's longer, lower cars. Load-Levelers* give 35% to 45% more road clearance with overload, 12% to 17% more road clearance with normal load.**

Load-Levelers* do the work of elaborate suspension systems—at a fraction of the price. Installed in place of the rear shock absorbers, they automatically adjust a car to any extra load, to provide a safe, comfortable ride.

- **Prevent "tail drag", side sway, and "bottoming" on axles . . . provide a smoother stable ride.**
- **Prevent hard steering and excessive tire wear.**
- **Require no service, and don't interfere with underbody servicing.**
- **Easily installed as optional equipment.**

Our engineers will be glad to discuss the many advantages of Load-Levelers*. Write or call today.



MONROE

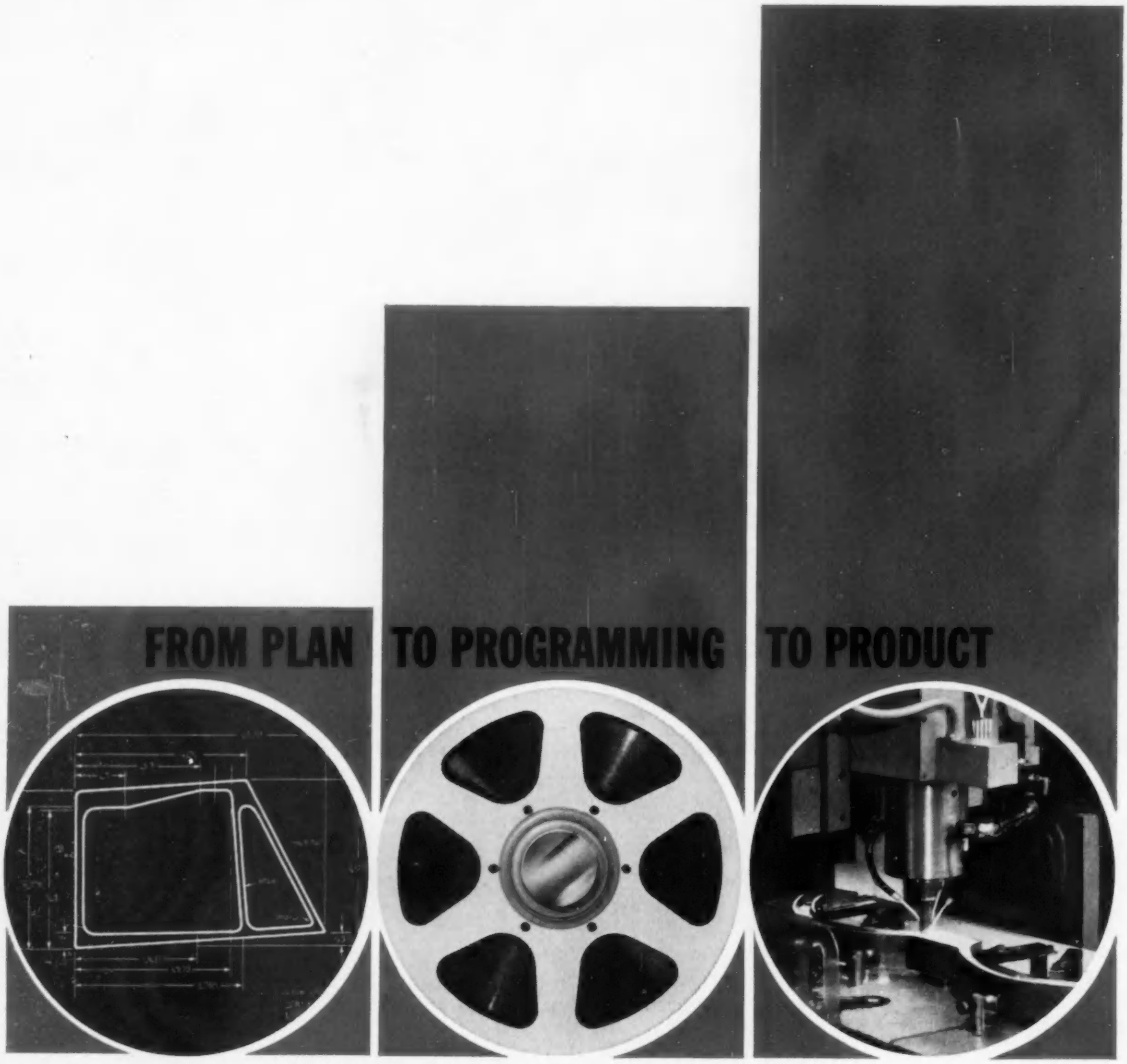
Load-Leveler
TRADE MARK
STABILIZING UNIT

*Trademark

MONROE AUTO EQUIPMENT COMPANY • MONROE, MICHIGAN

In Canada, MONROE-ACME LTD., Toronto, Ontario • In Mexico, MEX-PAR, Box 21865, Mexico City

WORLD'S LARGEST MAKER OF RIDE CONTROL PRODUCTS, INCLUDING MONRO-MATIC* SHOCK ABSORBERS



COMPLETE NUMERICAL CONTROL SERVICE FROM ROHR. Rohr Aircraft Corporation has established a complete, *in-plant* Numerical Control Department, offering a full range of services that can be tailored to any requirement. If you use numerically controlled machine tools, or recognize the method's superiority, this new service will interest you.

Rohr can provide complete service—tool planning, tool manufacture, part programming, computer processing, tape or card preparation, final part machining—or any part of the service separately.

If you own a machine, for example, Rohr will produce tape or card media from your plans. Or you may need to employ only computer or director service. Whatever your numerical control needs, this fully flexible service can meet them.

Rohr's recognized leadership in the use of numerically controlled machine tools and in programming stems from an early realization of the method's potential in production of uniform, close-tolerance parts. Studies began more than a decade ago—years before the first machines were built. Today, Rohr's complete facilities, practical experience, and highly trained staff combine to provide an unparalleled capability in numerical control.

A new brochure describes Rohr's numerical control services in detail.
Write Mr. A. R. Campbell, Sales Manager, Rohr Aircraft Corporation, Chula Vista, California.

WORLD'S LARGEST PRODUCER OF COMPONENTS FOR FLIGHT • CHULA VISTA AND RIVERSIDE, CALIFORNIA

ROHR
AIRCRAFT CORPORATION

Communication Plays Big Role in Expense Control

Based on panel report by

C. H. HOLLISTER

Case Institute of Technology

COMMUNICATION plays a most important role in expense control. Hollister's Law states: "In an expense control system, the greater the number of figures the less communication takes place." Following are specific rules developed from the Law which are designed to simplify communication and thereby provide better expense control.

Keep the Message Simple — Use three-digit numbers. They will get the message across and prove much more effective as to remembering and as to comparison. It is difficult for most people to compare two or more numbers if they are composed of over three digits. Chop off the extra digits. The additional accuracy of extra digits defeats the purpose of the report.

Keep Report Pages Small — If you have more three-digit numbers than will go onto a sheet of $8\frac{1}{2} \times 11$ paper, throw some away; you probably have too many. When you have reduced the amount of numbers to a minimum, keep them on $8\frac{1}{2} \times 11$ paper. Two, or even ten, sheets this size are better than a piece of wallpaper.

Keep Type Size Large — Many managers have less than 20/20 vision (or even hindsight). Make the contents of the report easy to see so it won't be avoided and so it can be understood.

Keep the Message Timely — Control information about historical events which can no longer be remedied is useless. A report is supposed to give a supervisor information upon which he can base a new decision about action desirable to remedy a situation. You cannot improve an operation that was discontinued a month ago.

Keep Report Elements Appropriate — There's no point in giving a works manager any figures on "his depreciation" unless you ask his help in setting depreciation rates. There is little purpose in talking "profits" to any manager when there is an arbitrary amount taken out of his profit margin for "general administrative overhead" — over which he has no control.

Maintain Realism of the Controlled — Don't allow fictitious accuracy. There is no sense in dollar and cents digit chasing all through a report if the total includes an item which is estimated at $10,000. Don't allow ridiculous assumptions. Why depreciate a building over a 50-yr life when built on a mineral deposit with a 15-yr life?

Make the Controls Fit the User — Use the language, and the form, and the mathematics of the report user — not the report maker. If he wants units, give him units — if he wants dollars, give him dollars. If he wants a chart, give him a chart. You're not trying to reform him, you're trying to help him operate better. Manufacturing control systems have no value if not understood by the individual making decisions about the expenditures under control. It's far easier to make the reports suit him than it is to make him learn your way of using reports.

Use the Exception Principle — Flag the elements out of line by using the exception principle, that is, draw attention to the things which are not going as you expected. The fact that you emphasize exceptions indicates that you had some specific goals or objectives in setting up budgets or forecasts or controls in the first place.

The material in this article was presented during a panel session on Manufacturing Expense Control. Other contributors on this panel were: chairman **R. M. Lynas,** Thompson Ramo Wooldridge Inc.; secretary: **H. J. Foehringer,** Thompson Ramo Wooldridge Inc.; **G. B. Howell,** Leece-Neville Co.; and **R. M. Svoboda,** Harris-Intertype Corp.

•

(This article is based on a report of one of 11 panels on production subjects. All 11 are available as a package as **SP-330.** **See order blank on p. 6.**)

NOW...
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...with 2 New RCI EPOTUF
Epoxy Hardeners

● You can control the degree of hardness or flexibility of your cured epoxy systems—when you use RCI EPOTUF Hardeners 2611 and 2613.

By blending the two, in conjunction with an epoxy resin, a formulator can easily and dependably produce systems that will result in hard, flexible or resilient products.

Each of the hardeners may be used individually . . . both are for room-temperature curing of epoxy resins.

EPOTUF Hardener 2611 is recommended in a simple 1:2 ratio with epoxy resins. It hardens the epoxy in 10 minutes to a hard, yet resilient, blush-free plastic. Because of its low viscosity, it handles easily and can be highly filled.

EPOTUF Hardener 2613 is generally used in a convenient 1:1 ratio with the epoxy resins. It cures rapidly with an unusually low exotherm. The flexible, blush-free system it provides has up to 100% elongation in a cured epoxy with total recovery.

Tensile strength of these systems will range from 2,000 psi to 14,000 psi.

Perhaps the controlled flexibility possible with these versatile new EPOTUF Hardeners can improve your epoxy systems. Write to RCI for complete technical information.

RCI *Creative Chemistry . . . Your Partner in Progress*

REICHHOLD

Synthetic Resins • Chemical Colors • Industrial Adhesives • Phenol • Hydrochloric Acid • Formaldehyde • Phthalic Anhydride • Maleic Anhydride
Ortho-Phenylphenol • Sodium Sulfite • Pentaerythritol • Pentachlorophenol • Sodium Pentachlorophenate • Sulfuric Acid • Methanol

REICHHOLD CHEMICALS, INC., RCI BUILDING, WHITE PLAINS, N.Y.

New Members Qualified

These applicants qualified for admission to the Society between June 10, 1960 and July 10, 1960. Grades of membership are: (M) Member; (A) Associates; (J) Junior.

Atlanta Section: George Radnoti (M), James H. Reynolds (A).

Baltimore Section: Thomas Phillip Clegg (A).

Buffalo Section: Ronald N. Crossley (M), W. Russell Laidlaw (M), E. Grant Pike (M).

Central Illinois Section: B. A. Berkeland (J), Clarence R. Fahnestock (M), Russell Marvin Jornd (M), Lawrence Stephen Tadie (J).

Chicago Section: Ralph C. Archer (M), Eugene S. Baranowski (M), Julian L. Chalk (J), Robert L. Fels (A), Francis L. Foley (A), Robert Paul Heffernan (A), William J. Kasper (A), Clifford R. Linker (M), Thomas H. Reddington (M), Robert R. Reid (M), Donald Michael Szymanski (J), Peter Teenstra (M).

Cincinnati Section: John S. Knox (M).

Cleveland Section: Coy Allen (M), Raymond F. Darney (M), Victor Holt, Jr. (A), Wolfgang Fred Ligotke (A), James D. McCaskey (A), Frank Van Syckle Smith, Jr. (J), George R. Voss (M).

Dayton Section: Alexander A. LePera (M), Byron L. Watson (J), Yoshitaka Yoshida (J).

Detroit Section: Algirdas L. Ancevicius (J), Bruce H. Bacon (J), Robert O. Bowersox (A), Richard Million Burke (M), Donald F. Buser (J), Charles G. Chase (M), Traian T. Comsa (M), E. Clifford Dudley (M), Paul D. Fadow (M), Richard E. Gerhardt (M), L. D. Gschwind (J), George W. Hain (A), Donald A. Hulett (A); A. P. Stanley Hyde (J), Martin S. Kilsdonk (A), Grover C. Lawson (M), Joseph E. Lober (A), John H. Mieras (J), William S. Morrison (M), Victor A. Nawrocki (M), James N. Neumann (M), John J. Pathe, Jr. (J), Robert D. Petrie (A), Louis D. Phillippi (A), Grover S. Ramsey (M), James Bennet Robbins (A), George V. Rouke (M), Nolan A. Ryan (M), W. J. Scarborough (M), Jewell Richard Smith (A), Ronald F. Steinmayer (J), Duane L. Te Selle (J), Martin Tomka (M), Andrew J. Van-

continued on p. 144

New Members Qualified

continued from p. 142

Hoef (A), Bernard A. Wehring (M), Robert F. Wheaton (J).

Indiana Section: Carl T. Hardt (M), Warren C. Letsinger (M), Walter A. Wolf (M).

Kansas City Section: George C. Hilaire, Jr. (M).

Metropolitan Section: Daniel T. Cahill (M), William Morrison Dempsie (M), Albert G. Feil (J), Cord Lipe (M), Stuart M. Sachs (M), Leroy Simpson (M), Michael J. Walsh (A).

Mid-Michigan Section: Robert P. Hendrichs (A), John W. Roth (A), Howard P. Siegel (M).

Milwaukee Section: David H. Phillips (M), Richard Thomas Scantlebury (M), John A. Strachota (J), Robert T. Thompson (M).

Montreal Section: John S. Bell (A), Cyril Alan Randall (M).

Northern California Section: John H. Blakney, Jr. (A), Frank E. Frosburg, Jr. (M), Edward M. Ritts (M), William Edward Sytz (J).

Northwest Section: Lloyd H. Stearns (A).

Ontario Section: Duncan Alexander Brodie (J), Donald M. Campbell (M), Harold G. Deline (M), Robert Elgin Parkinson (J), George Raymond Porter (A), Ron W. Todgham (M).

Philadelphia Section: John A. Delaney (A), Michael Gochtovtt (M), Robert H. Sinnamon (M).

Pittsburgh Section: George C. Tunis, Jr. (J).

Rockford-Beloit Section: Norman L. Rice (M), Lynn Osborne Twedt (M).

Southern California Section: Aaron Bloom (M), James B. Gregory (M), Victor Francis Hickey (A), Michael S. Patitucci (M), Richard R. Prothero (M), Everett H. York (A).

continued on p. 147

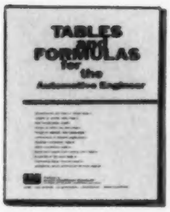
50 Tractors

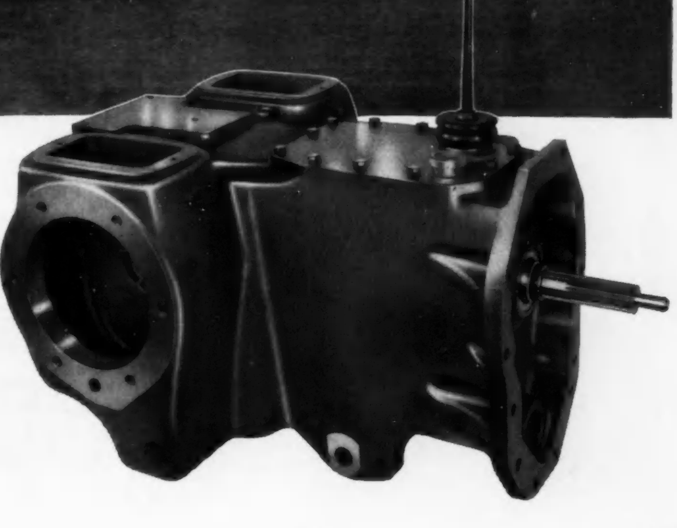
all with Clark transmissions

Here is *Allis-Chalmers' complete line* of farm and utility tractors. Fifty models in all—*all equipped with Clark transmissions and differentials.*

The selection of these power train units is the result of a pooling of Allis-Chalmers engineering experience in farm machinery and Clark's unique knowledge of engine-power transmission. Clark, in its 57 years, has built millions of heavy-duty transmissions—Allis Chalmers engineers report *their* Clark units are smooth-working . . . *quiet* . . . rugged . . . *thoroughly dependable* . . . extremely long-lasting.

If *you'd* like to know about the many advantages of a Clark transmission as applied to *your* tractor, truck or other vehicle—write us. We'll be glad to send you literature showing the complete Clark transmission line. We'll also send you, while our supply lasts, a helpful new booklet containing 24 pages of special automotive engineering tables and formulas. Free. No obligation.





SEE US AT THE SAE ENGINEERING DISPLAY, MILWAUKEE, SEPTEMBER 12-15. BOOTH 207

CLARK® EQUIPMENT

CLARK EQUIPMENT COMPANY
AUTOMOTIVE DIVISION
Jackson 5, Michigan

New Members Qualified

continued from p. 144

Southern New England Section: Theodore M. Adgate (M), William T. Blake (M), Raymond S. Gervais (M).

Syracuse Section: George T. Jarrett (M).

Texas Section: M. A. Atkins (M).

Western Michigan Section: Robert E. Bishop (A), Melvin F. Brugger (A), J. F. Oehlhoffen (M).

Outside Section Territory: Lawrence Graham Bannatyne (A), Arthur S. Gloster, II (J), Roscoe Andrew Scott (A).

Foreign: Salvador Arena (M), Brazil; Kenneth W. H. Baldock (M), Australia; Daniel Del Valle Pena (J), Mexico; Louis William Evans (M), East Africa; Aurele P. LaMere (M), Turkey; Frank Will May (M), England; Leslie Ronald Prout (M), England; M. Unnikrishnan (J), India.

Applications Received

The applications for membership received between June 10, 1960 and July 10, 1960 are listed below.

Atlanta Section: Wellington H. Force

Baltimore Section: Everett W. Taft

British Columbia Section: Goro Nishimura

Buffalo Section: Norman Stuart Dean

Central Illinois Section: Jack Wayne Carter

Chicago Section: William Harrison Bateman, Jr., Roy A. Decker, Frank William Jenks, Karel Klima, Allan F. Kubista, Robert G. Lofgren, Walter A. Slowik

Cincinnati Section: Fred August Ziegler

Cleveland Section: Ralph C. Axsom, David N. Olson, Austin E. Pettyjohn

Colorado Group: J. Wayne Glauser

Dayton Section: Jerome L. Dorsten, Frederick R. Landig, Gordon Sterling Mead

Detroit Section: Charles E. Baker, Sr., R. Stewart Fleming, Thomas Russell Forrester, Aloysius J. Kochanski, Roger J. Kukkola, Tim Frank Lezotte, Reino H. Mustonen, Ernest Secules, Richard Emory Smith.

Fort Wayne Section: Robert Gordon Nelson

Indiana Section: Reasel H. Ashmore, Jr.

Kansas City Section: Clyde C. Engert

Metropolitan Section: Donald Parker Brenz, Frederick M. Jackson, Jr., Wilson Kokalari, Ronald Franklin Krieger, Albert E. Lyons, George Henry Marks, Frank Warren Oswald, Frank Ring, W. Wallace Sellers, Jr.

Mid-Michigan Section: James Andrew Chipman, John Edward Morlock, W. H. M. J. Vander Horst

Milwaukee Section: Thomas William Baehler, Joseph Frank Heil, Leonard John Hunsader, Jan Lynn Peterson, Robert Allen Pettingill, David H. Stieber

Montreal Section: Bryan Thomas Baker, Louis Morin

New England Section: Maurice Gertel, Peter E. Glaser

Northern California Section: George C. Donovan, Akito Ogoshi

Ontario Section: Sydney Leon Britton, George A. Lacy, Peter Ronald Trollope

Oregon Section: Earl S. Presten

Philadelphia Section: Charles Carroll McClelland

Rockford-Beloit Section: Robert L. Lewis, Laurence G. Olson

San Diego Section: Douglas Larry Bledsoe

Southern California Section: William Pitts Baxter, Wilson James Elder, Scott Fenn, Ernest Lloyd Phelps, William Fred Pieper

Southern New England Section Douglas Gale Culy

Texas Gulf Coast Section: Richard S. Manne

Western Michigan Section: C. R. Goodman

Outside Section Territory: Hansford Barbour Anderson, Boyd Elliott Falk, William Alexander Hewitt, S. H. Mitchell, Harold Earl Wenninger

Foreign: William Douglas MacTaggart Black, Australia; Howard Arthur Pendergast, Australia; Tetsujiro Ozono, Japan; Julian Manuel Irigoyen, South America; Oktay Mustafa Erenturk, Turkey; Oswaldo Guada, Venezuela

All 1960 U.S. cars use

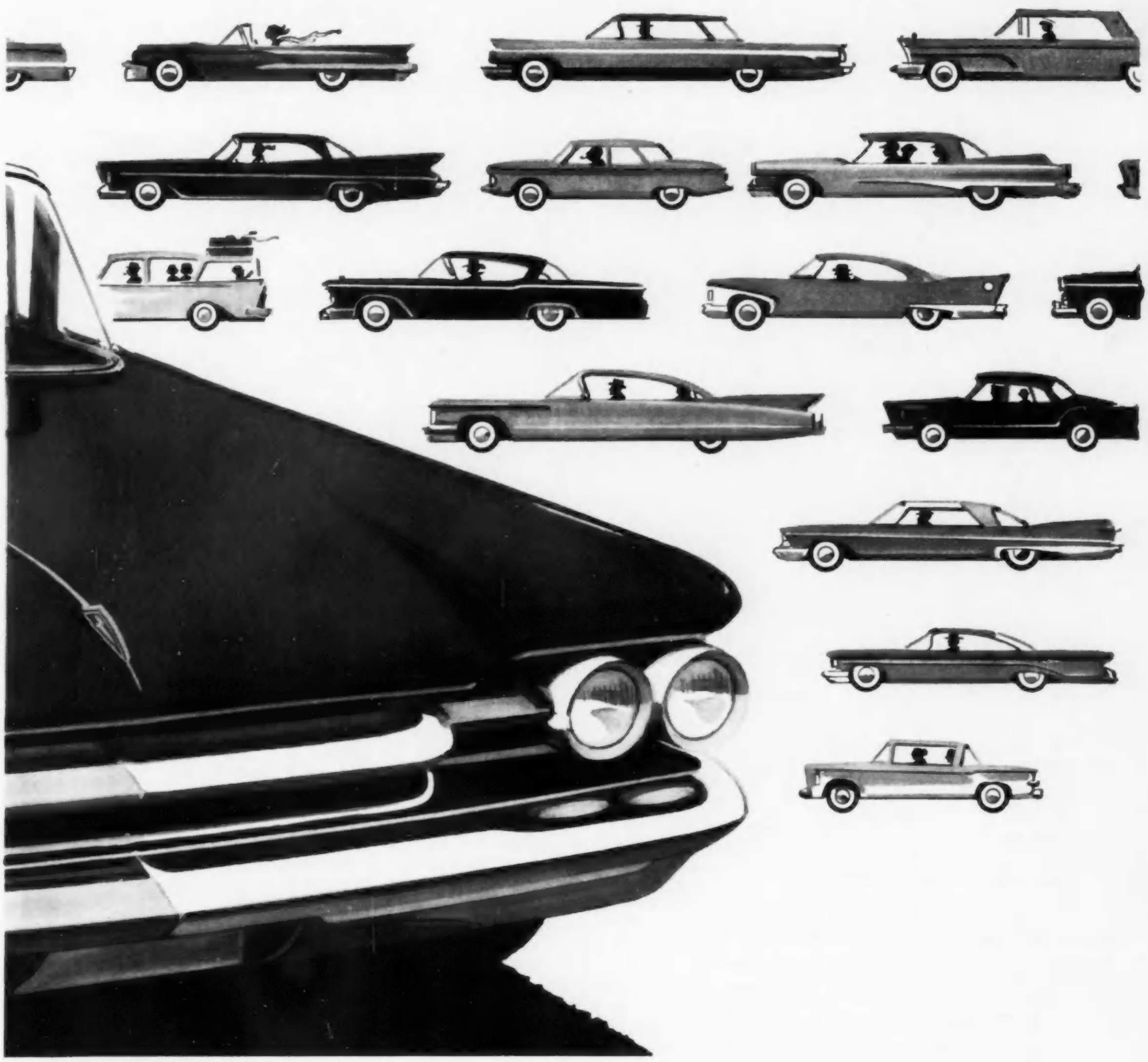
Parts made of high performance Enjay Butyl rubber are to be found on every one of today's U.S.-made cars! Over 100 applications . . . dozens of separate parts on some cars!

Butyl was selected because of its many outstanding properties . . .

Resists weathering, sunlight, ozone, moisture, mildew – in weather-stripping, seals, convertible tops and other parts.

Deadens vibration and sound Smooths the ride – in tires, tubes, and drive-shaft insulators. Muzzles squeaks – in shims, sheet-metal seals and insulation.

Absorbs shock Dynamically softer as well as shock absorbent – cushions bodies, bumpers, and motors.



ENJAY BUTYL rubber!

Beats the heat Stands up in under-the-hood service – in radiator hose, firewall grommets, hood bumpers, and gaskets.

Resists tear, flex, abrasion Checks deterioration – in cable bushings, accelerator bellows, pedal pads and gear-shift lever boots.

Enjay Butyl rubber is second to none in good looks . . . it's easy to color and finish smoothly. For more information contact the nearest Enjay office.

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ENJAY® BUTYL

Recognized "Hauling Card" on America's Leading Trailers

Because Rockwell-Standard® supplies axles (Rockwell-Standard and Timken-Detroit) in such volume and in so many different forms to meet a constantly growing variety of requirements, it has become one of the best known names within the automotive field.

For more than 50 years Rockwell-Standard has been an aggressive pioneer of new axle designs and development. Today, with six modern plants devoted to the exclusive production of axles and related components, combined with modern research and testing facilities, Rockwell-Standard is a vital factor in the growth and success of the truck-trailer industry. Only Rockwell-Standard offers all these outstanding benefits to its customers — *benefits no trailer manufacturer could economically afford or duplicate on his own.*

ONLY ROCKWELL-STANDARD OFFERS:

1. **Complete Line of Axles in Wide Range of Capacities.**
2. **50 Years of Know-How and Experience.**
3. **Complete Design, Research and Service Organization.**
4. **Ready Reservoir of Labor and Material to Meet Varying and Seasonal Demands.**
5. **World's Most Modern and Extensive Axle Building Facilities.**
6. **Undivided Responsibility for Complete Component.**
7. **Dependable Products with Years of Established Acceptance.**

Product of...

World's Most Specified Axles for Truck Trailers

ROCKWELL-STANDARD
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A CONSOLIDATION OF THE TIMKEN-DETROIT AXLE COMPANY AND STANDARD STEEL SPRING COMPANY

Transmission and Axle Division, Detroit 32, Michigan

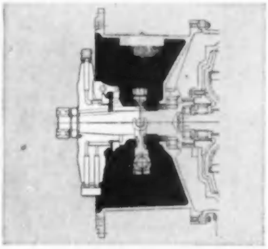
You'll put permanence into products with Western Brass because


EVANS HEATERS ARE RIGHT
FOR TRUCKS BECAUSE
THEY'RE BUILT FOR TRUCKS!

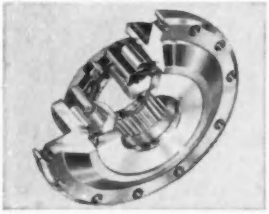
OPTIONAL

NEW From TWIN DISC . . .
Single-Stage Torque Converter
WITH DISCONNECT CLUTCH

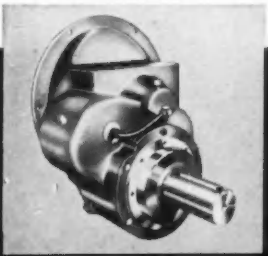
"C" WITH FRONT-END DISCONNECT CLUTCH (STANDARD)



"O" WITH OVERSPEED OR BOOM-LOWERING FREEWHEEL



"G" WITH 2:1 RATIO OUTPUT REDUCTION GEAR



IN THE APPLICATION of single-stage torque converters, Twin Disc's new *Model C* units provide considerable design flexibility. These clutch-equipped converters are offered in three input torque capacities: 350 lb-ft (1300 Series); 450 lb-ft (1500 Series Standard-Duty); and 650 lb-ft (1500 Series Heavy-Duty).

All Model C units feature an 11″ front-end disconnect clutch—single-plate on the smaller series; two-plate for capacities above 350 lb-ft. Both clutches are mechanically actuated types with driving rings that fit standard SAE over-center flywheels.

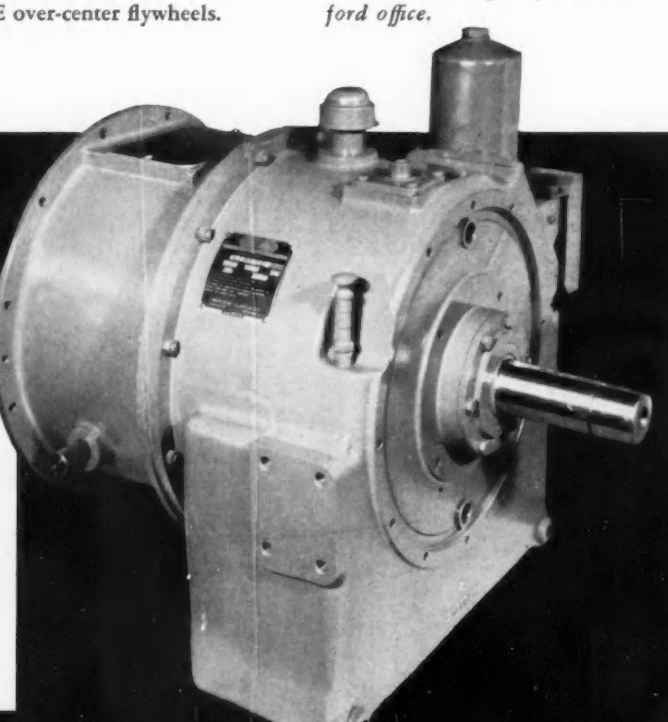
OPTIONAL
Boom-Lowering Freewheel

For the shovel and crane industry, Twin Disc has designed a special converter—*Model CO*—with a cam-and-roller freewheel between the impeller and the turbine. This permits the converter to function as a straight mechanical drive whenever the output shaft is driving. As the boom begins to fall of its own weight, the freewheel locks the turbine to the impeller, making engine friction horsepower available for braking.

OPTIONAL
Output Reduction Gear

For installations using high-speed engines but requiring lower output shaft speeds, Twin Disc can furnish a 2:1 ratio reduction gear. It bolts to the rear of all Model C and CO converters and is capable of carrying output shaft side loads. The gear can be mounted in the field without design change.

New Bulletin 510, containing engineering data on 25 models of Twin Disc Single-Stage Torque Converters, is available on request from our Rockford office.



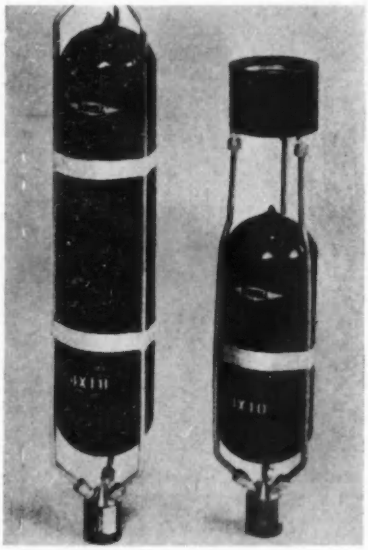
TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES

TWIN DISC
Torque Converters

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin • Hydraulic Division Rockford, Illinois

THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING



NEW WAY TO TICKLE A "TRICKLE" WELL

For some centuries now, great bangs around the globe have borne witness to man's sometimes happy faculty for putting to work the phenomenon we call "explosion."

Now we are finding ways to make use of *im*plosion. And glass is helping us.

Supposing your oil well starts to ooze instead of gush. You take one of the devices shown above and lower it into the well. Fill the hole with fluid and apply pressure. When the psi reach a set level, you get a squoosh and then a whoosh and then—with luck—a gush of oil.

The squoosh signals an implosion; the whoosh, a counteracting explosion in the fluids. Working together, the two forces develop pressure waves up to 20,000 psi, usually enough to fracture the surrounding strata and to stimulate the flow of any oil present in the formation.

The service using these capsules is called Rockshock;* it was developed and is offered by Dowell Division of The Dow Chemical Company. The capsules are made from PYREX® brand glass blanks which we supply. The capsules are evacuated to extremely low pressures.

We make the composition of the glass blanks and their wall thicknesses to exactly the right specifications so that the capsules will implode at specified pressures.

We make the glass so that it will *dice* when it implodes, disintegrating instantaneously to pieces small enough to pass through valves and pumps without damaging them.

At the same time, we make the glass sturdy enough so that you can handle the capsules used in Rockshock above ground with as much safety as glass bottles.

Dowell can tell you more about Rockshock. They are in Tulsa, Oklahoma. We can tell you more about the marvels of glass . . . say, in our Bulletin B-83, titled "Properties of Selected Commercial Glasses." We are in Corning, New York, and can be reached by coupon.

*Dowell Service Mark

STEAM GAUGE THAT WORKS LIKE A TRAFFIC LIGHT

When you see red, you're looking at live steam. When you see green, you're looking at water.

It's as simple as that with this new Multi-Port gauge from the Diamond Power Specialty Corporation.

Like so much that's simple, this takes a fairly complicated system of optics, for which we supply the glass.

Like so much that's complicated, this optical system takes advantage of a simple fact, namely, water and steam have different refractive indexes.

At the rear of the gauge a group of sealed-beam lamps (we probably made the glass for these, too!) throw light on two colored pieces of glass. One is red, the other is green. If the light then passes through steam, only the red portion gets through to the viewing port. Vice versa for water. If the water level falls half way up a port, you see both red and green with a sharp line of demarcation at exactly the right level.

You can see the gauge in the dark. Since light has the swiftest of all movement, there is absolutely no time lag when the steam level changes.

Aside from its optical properties, the glass we provide has to take the thermal shock of live steam, the corrosive environment of steam and water, and pressure up to 3000 psi.

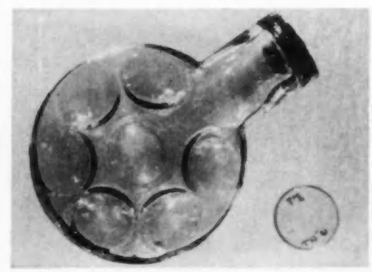
Actually, these are simple conditions for us to meet, as you'll discover, if you ever have occasion to put one of our glasses to work.

Bulletin IZ-1, "Designing with Glass for Industrial, Commercial, and Consumer Applications," can help you spot such occasions. The coupon will fetch you a copy.

WHY EYEGLASS LENSES DON'T COME IN BOTTLES ANY MORE

In 1912 this flask was a marvel of mass production. With just a few good puffs one of our glassblowers could produce blanks for a dozen or more eyeglass lenses.

Now look at the lens blank in the corner of the picture. It has the stamp of technology all over it. Code letters and numbers. Nicely finished edges. Each one like the other.



Now we have machines to stamp out lens blanks . . . even bifocal lens blanks . . . by the millions without a glassblower drawing breath.

A perfect example of our willingness to sacrifice the romance of handcrafting to the sheer economy and efficiency of machinecrafting whenever it will benefit our customers.

The only interest we expect you might have in all this is in this simple fact: we have *two* kinds of versatility to sell. The versatility of glass itself. The versatility of methods in manufacturing from glass.

We can cast giant mirrors and windows for radioactive cells, blow delicate bubbles for lab ware, press or roll great masses for items needed in large quantities in a hurry . . . in short, we can put to work practically every manufacturing method known to man to put your product in glass.

"This Is Glass" is a booklet that tells more about these methods and glass itself. It's in the coupon.

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS, 40 Crystal St., Corning, N. Y.

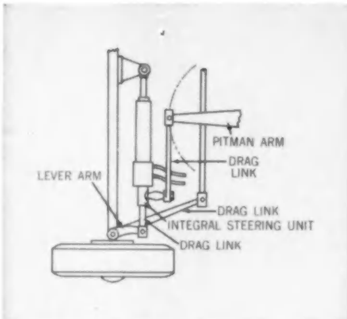
☐ B-83; ☐ This Is Glass; ☐ IZ-1

Name...Title..................

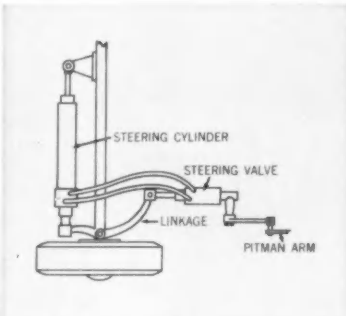
Company...

Street...

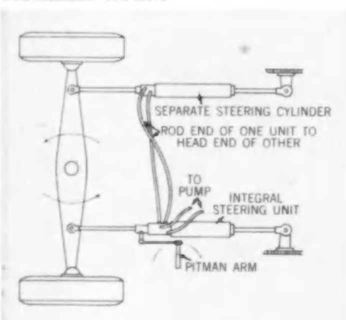
City...Zone..........State..........



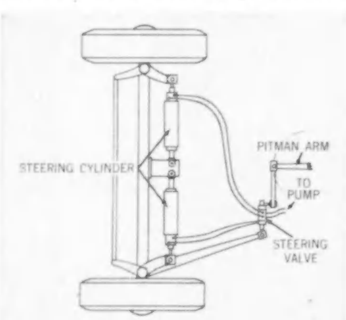
INTEGRAL LINKAGE system combines servo valve and steering cylinder with rod end fastened to frame and valve end to drag link.



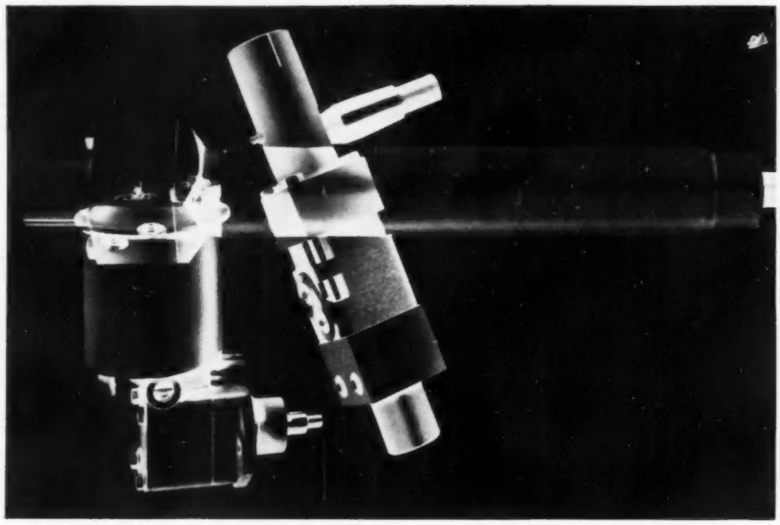
REMOTE LINKAGE system has separate servo valve and cylinder. Servo is mounted at most convenient point with cylinder located for maximum thrust.



COMBINED INTEGRAL-REMOTE system servo valve controls both cylinders. When integral unit (bottom) extends, remote unit (top) retracts.



REMOTE DUAL system uses one remote servo valve, offers best possible thrust conditions plus considerable installation flexibility.



FOR AXLE LOADINGS 1500—128,000 LBS.

New VICKERS. power steering systems use standard units, offer custom performance

Performance benefits normally associated with custom designs plus the economy of standard, production-built components are combined in new Vickers power steering systems. The cylinder, servo valve, and pump—key elements in the power steering system—are always perfectly matched to system needs because Vickers builds the *complete system*.

Either remote or integral systems can be provided for the complete range of axle loadings from 1,500 to 128,000 lbs. All vehicles use the same servo valve—holding engineering and installation time to a minimum and reducing inventory requirements for manufacturers building several sizes or types of equipment.

Operating Economy—Systems are designed for high pressure operation (to 2000 psi) permitting smaller pumps, lines, reservoirs, valves and cylinders to be used. Further economy results because each basic size of steering unit is capable of a wide range of axle loadings. This permits some manufacturers to use a single size of steering unit for their complete line of vehicles. For example, in a single cylinder installation, the Model SC-26 cylinder can be used for any axle loading from 16,000 to 64,000 lbs.

Further economy over the life of the system results from the minimum number of moving parts required by this design and from its rugged construction. All cylinders are double walled to eliminate the common hazard of functional damage to cylinder walls from flying debris. Exclusive design vane pumps last longer, permit easy cold weather starting because pumping doesn't begin until after engine fires and comes up to speed.

Complete Responsibility — Both the equipment builder and ultimate user benefit because Vickers designs and builds all system components. In addition, a staff of power steering specialists is available to work with customers on specific development and application problems.

When equipment is being built for the export market, worldwide stocks and complete interchangeability of all parts made in Vickers plants throughout the free world offer added benefits.

More Data — Design advantages, dimensions, ratings, and other data are available in Bulletin titled "New Complete Power Steering Systems." Write for this 20 page Bulletin M5110.

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

Mobile Hydraulics Division

ADMINISTRATIVE and ENGINEERING CENTER

Department 1440 • Detroit 32, Michigan

Application Engineering Offices: • ATLANTA • CHICAGO CINCINNATI • CLEVELAND • DETROIT • HOUSTON • LOS ANGELES AREA (El Segundo) • MINNEAPOLIS • NEW YORK AREA (Springfield, N.J.) • PITTSBURGH AREA (Mt. Lebanon) PORTLAND, ORE. • ROCHESTER • SAN FRANCISCO AREA (Berkeley) • SEATTLE • ST. LOUIS • TULSA

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8901

A lifetime of light crammed into 15 days

A lifetime of light crammed into 15 days

Tung-Sol headlamps are subjected to the severest set of tests in the industry — from raw materials to finished product — before they reach the highways of the world.

One of the most critical final examinations they face is the life test. First, samples of each production run are checked for maximum candle-power, amperage and wattage at design volts. They are then placed in the aging racks and burned at accelerated voltages to assure full completion of their designed life. In this case the low beams of 12 volt headlamps burn continuously at accelerated voltages for fifteen days to make sure they'll produce the 500 hours of peak performance required by S.A.E. specifications.

This test is an example of Tung-Sol's leadership in quality mass production of headlamps . . . leadership which started at the turn of the century when Tung-Sol produced the first successful electric headlamp. Automotive Products Division, Tung-Sol Electric Inc., Newark 4, New Jersey. TWX:NK193.

TUNG-SOL® HEADLAMPS · MINIATURE LAMPS · FLASHERS

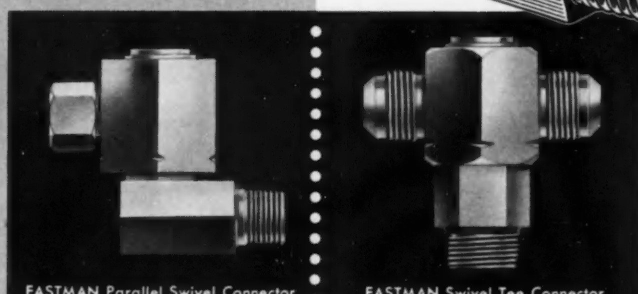
Eastman

improves INDUSTRIAL SWIVEL CONNECTOR

Licensed Under
Pat. No. 2481404

AMAZING VERSATILITY AND ADAPTABILITY!

These two adaptations, specified by two of America's largest major equipment manufacturers, reveal the unique adaptability and versatility of EASTMAN'S improved Industrial Swivel Connector.



EASTMAN Parallel Swivel Connector

EASTMAN Swivel Tee Connector

improves **SEALING QUALITY**
through use of SIX seals, thereby eliminating failure from grit, dust and other foreign materials.

improves **SERVICE LIFE**
through new design and engineering, the interior is chrome-hardened with a highly polished mirror finish.

improves **UNIFORMITY OF FLOW**
at any angle of the swivel by undercutting the shaft to equal diameter of the orifice.

improves **SERVICEABILITY**
through shorter, more compact housing; saving weight. Hex design permits multiple tapping on housing; easier assembly.

While the use of EASTMAN'S High Pressure Industrial Swivel Connector eliminated the cause of hose failure due to constant, extreme flexing, it tended to increase the load on the swivel connector.

To improve the performance of the swivel itself, EASTMAN engineers improved its internal design, chrome-hardened its interior surfaces, cadmium plated the shaft and then machined them to a mirror-like finish.

Satisfactory service under the most unfavorable field conditions was insured by increasing sealing rings from four to SIX: 2 leather dust seals, 2 synthetic back-up washers and 2 quad rings of oil-resistant rubber (−65° to +250°).

Exhaustive tests at 3000 p.s.i., through one million cycles, with the hydraulic fluid *saturated* with abrasives, dirt and other foreign materials, proved EASTMAN'S Industrial Swivel Connector satisfactory in every respect and did not cause failure of any kind.

That is why America's leading OEM's and replacement buyers specify *complete* EASTMAN Hydraulic Hose Assemblies . . . for improved design, quality manufacturing and exhaustive testing. It pays to specify EASTMAN.

STANDARD SIZES AND COMBINATIONS AVAILABLE

LOW TORQUE—Freedom from friction, even under high pressure.

WIDE RANGE—Operating pressures up to 5000 p.s.i. trouble-free operation through wide temperature range (−65° to +250°).

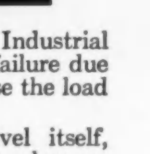
ROTATION—Full 360° for all manifolds.

SIZES—Steel, plated for corrosion protection—½″, ¾″, 1″, 1¼″.

Other sizes available on request.

LOOK INTO EASTMAN'S IMPROVED SWIVEL CONNECTOR—WRITE TODAY!

Please send me Bulletins 100 and 200 on low, medium and high pressure assemblies.



Eastman MANUFACTURING COMPANY
DEPT. SAE-8, MANITOWOC, WISCONSIN

Wyman-Gordon makes a major

Wyman-Gordon makes a major .
Now parts are being forged in ·

Nickel-base high-temperature alloy 45" diameter 520 pounds

PHYSICAL PROPERTIES

TENSILE AND YIELD STRENGTHS

ALLOY*	TEST TEMPERATURE °F.	HEAT TREAT	GUARANTEED MINIMUM: ULTIMATE TENSILE STRENGTH PSI	GUARANTEED MINIMUM: 0.2% YIELD STRENGTH PSI	GUARANTEED MINIMUM: ELONGATION %	TYPICAL VALUES: ULTIMATE TENSILE STRENGTH PSI	TYPICAL VALUES: 0.2% YIELD STRENGTH PSI	TYPICAL VALUES: ELONGATION %
Waspaloy	RT	A	175,000	120,000	15.0	194,000	136,000	24.0
	1000	A	162,000	112,000	13.0	175,000	124,000	23.0
René 41	RT	B	180,000	132,000	12.0	200,000	150,000	15.0
	1400	B	135,000	115,000	13.0	145,000	125,000	18.0
Astroloy	RT	C	190,000	138,000	10.0	205,000	152,000	12.0
	1400	C	150,000	122,000	12.0	160,000	132,000	15.0
U-500	RT	D	175,000	120,000	10.0	195,000	135,000	12.0
	1400	D	125,000	105,000	12.0	140,000	120,000	15.0
M-252	RT	B	170,000	115,000	15.0	185,000	125,000	20.0
	1000	B	160,000	105,000	15.0	165,000	115,000	22.0

STRESS RUPTURE

ALLOY*	TEMPERATURE STRESS	GUARANTEED MINIMUM	TYPICAL VALUES
Waspaloy	1350°F.—70,000 psi	70 hours—6% Elongation	130 hours—16% Elongation
René 41	1350°F.—85,000 psi	30 hours—8% Elongation	60 hours—15% Elongation
Astroloy	1800°F.—20,000 psi	20 hours—7% Elongation	35 hours—12% Elongation
Udimet 500	1650°F.—25,000 psi	30 hours—6% Elongation	55 hours—12% Elongation
M-252	1500°F.—40,000 psi	30 hours—8% Elongation	55 hours—16% Elongation

Note: The guaranteed minimums are based upon radial and tangential test locations.

BROAD RANGE OF GAS TURBINE COMPONENTS ALSO BEING PRODUCED IN:

- Low-Alloy, High-Strength Steels
- Intermediate-Temperature Alloys
- Titanium and Refractory Metals
- Aluminum and Magnesium

High-strength steel 19" diameter 143 pounds

COMPOSITION AND HEAT TREATMENT

CHEMISTRY

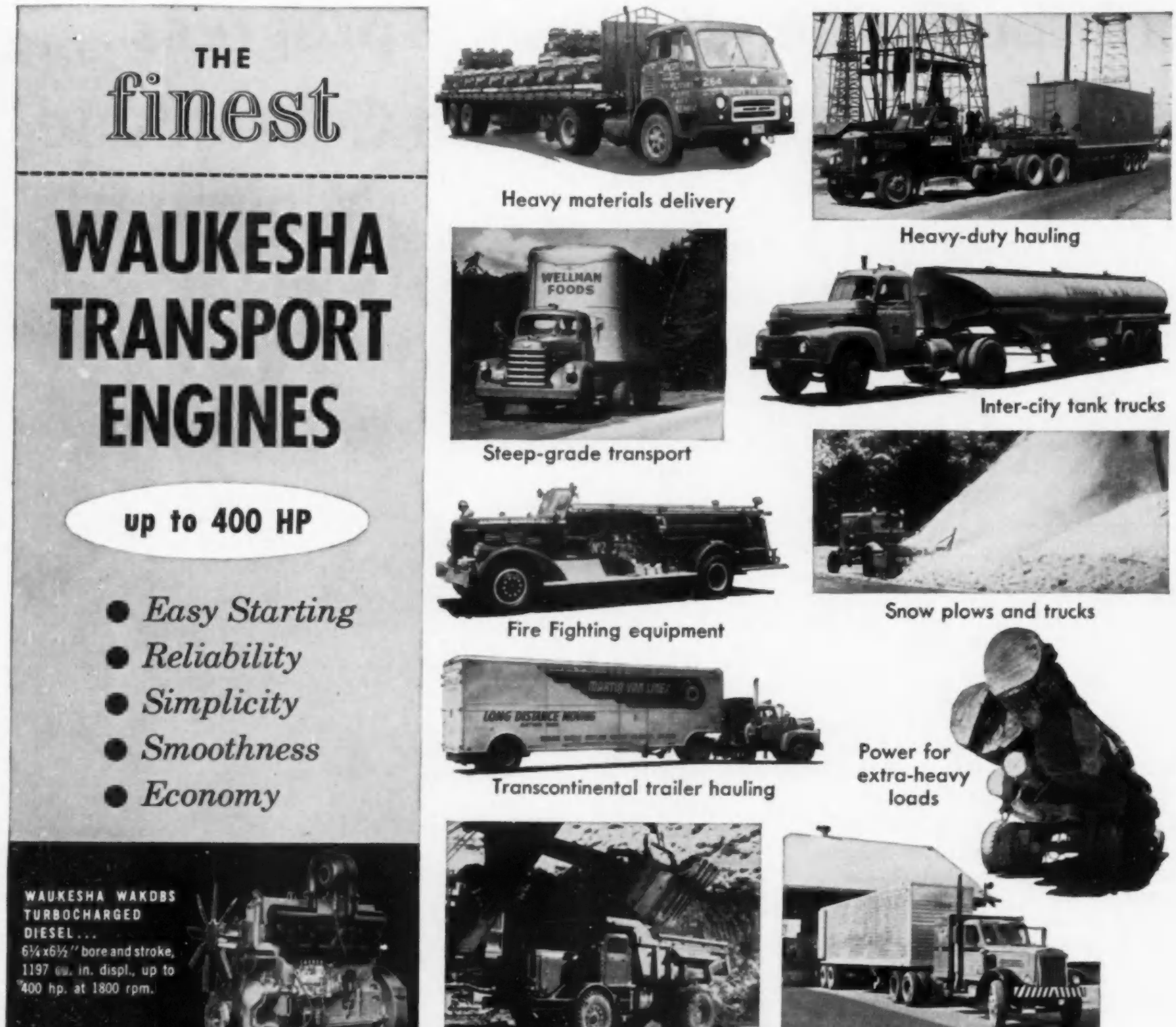
ALLOY*	C	Cr	Mo	Co	Ti	Al	B	Ni
Waspaloy	.08	19.0	4.3	13.5	3.0	1.4	.004	Balance
René 41	.08	19.0	10.0	11.0	3.1	1.6	.004	Balance
Astroloy	.05	15.0	5.0	15.0	3.5	4.3	.030	Balance
Udimet 500	.07	18.5	5.0	18.3	3.0	3.0	.003	Balance
M-252	.15	20.0	10.0	10.0	3.0	1.3	.002	Balance

HEAT TREATMENT

A.	1850°F.—4 hours—OQ; 1550°F.—2 hours—AC; 1400°F.—16 hours—AC
B.	1950°F.—4 hours—AC; 1400°F.—16 hours—AC
C.	2100°F.—½ hour—AC; 1400°F.—16 hours—AC
D.	1975°F.—4 hours—AC; 1500°F.—24 hours—AC; 1400°F —16 hours—AC

Note: Refer to appropriate heat treat code in Tensile & Yield Strength table.

*Waspaloy: Pratt & Whitney Aircraft Corp.; René 41, Astroloy and M-252: General Electric Company; Udimet 500: Metals Division, Kelsey-Hayes Company.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finest
WAUKESHA
TRANSPORT
ENGINES
up to 400 HP
Easy Starting
Reliability
Simplicity
Smoothness
Economy
Heavy materials delivery
Heavy-duty hauling
WELLMAN FOODS
Steep-grade transport
Inter-city tank trucks
Fire Fighting equipment
Snow plows and trucks
Transcontinental trailer hauling
Power for extra-heavy loads
Off-the-highway service
Overland freight routes
466
WAUKESHA WAKDBS TURBOCHARGED DIESEL...
6¼x6½" bore and stroke, 1197 cu. in. displ., up to 400 hp. at 1800 rpm.
WAUKESHA 145-GZB HIGH OUTPUT GASOLINE ENGINE
5⅜x6" bore and stroke 817 cu. in. displ., up to 268 hp. at 2400 rpm.
WAUKESHA WAKB BUTANE-PROPANE ENGINE
6¼x6½" bore and stroke, 1197 cu. in. displ., up to 300 hp. at 1800 rpm.
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GASOLINE
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EXCEPTIONAL PLANT FACILITIES
25 ACRES OF MANUFACTURING SPACE
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WAUKESHA MOTOR COMPANY
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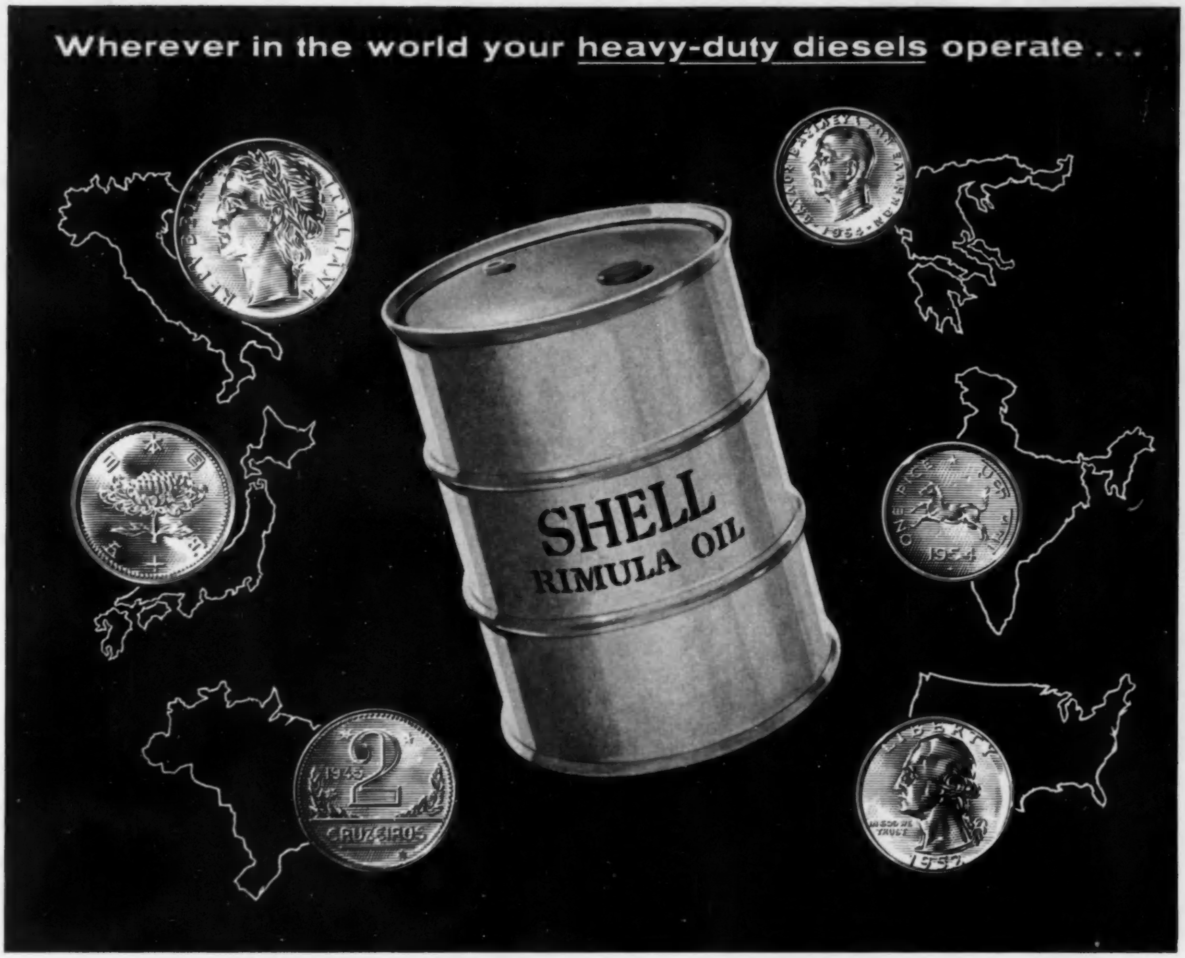
GRAFTON MASSACHUSETTS LOS ANGELES CALIFORNIA PALO ALTO CALIFORNIA FORT WORTH TEXAS



Shell Rimula Oil is there

Other outstanding Shell Industrial Lubricants

Shell Tellus Oils—for hydraulic systems

Shell Talona R Oil 40—anti-wear crankcase oil for diesel locomotives

Shell Alvania Grease—multi-purpose industrial grease

Shell Turbo Oils—for utility, industrial and marine turbines

Shell Dromus Oils—soluble cutting oils for high-production metalworking

Shell Macoma Oils—for extreme pressure industrial gear lubrication

Shell Voluta Oils—for high-speed quenching with maximum stability

AN INTERESTING FACT!
Every Shell Branded Industrial Lubricant is named for a sea shell. Shown here is the Rimula exquisita.

Around the world, Shell Rimula Oil is available—under the same brand name and providing the same efficient lubrication that your domestic customers rely upon.

Rimula® Oil is a heavy-duty oil that provides the finest crankcase lubrication for today's supercharged diesels. It has proved more than a match for the greatly increased engine ratings, high temperatures and pressures encountered in modern diesel operation. Rimula Oil successfully resists every destructive force that tends to accelerate engine wear.

The next time your specifications call for a heavy-duty crankcase oil, we suggest you order Shell Rimula Oil. Write or call today for complete information.

SHELL OIL COMPANY

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SHELL

• **A look at the**

DOW

Proving ground for

AUTOMOTIVE CHEMICALS

An automotive engineer, watching an instrument panel, makes deliberate calculations on a clip board. He's working out the details of a new automotive advance that will be introduced to the public three, perhaps four years from now. Miles away, a research chemist is doing the same thing in one of Dow's Automotive Chemicals Laboratories, helping to perfect a new chemical that will be needed for the automobile of the future. And, quite often, the two men are working together on the same research project . . . perhaps an innovation in the braking system. . . .

BRAKE FLUID RESEARCH PUSHES BOILING POINT TO 580°F!

Working closely with automotive engineers, Dow has developed new brake fluids that can withstand the heat of tomorrow's braking systems. Next step: Development of brake fluids of even greater capacity for the future.

Measuring brake fluid boiling points in Automotive Research Labs.

The capacity of brake fluids to take heat—the crucial point at which they boil and vaporize—is the subject of intensive work now in progress at Dow's Automotive Chemicals Laboratories. Many brake fluid formulations resulting from this work are available commercially today. They meet or exceed the recently tightened SAE specs.

On that all-important matter of boiling points, SAE 70R1 and SAE 70R3 heavy-duty specifications call for 300° and 375°F, respectively. Six different Dow-developed brake formulations offer boiling points ranging from 320° to 580°F! Thus the automotive designer can build a large margin of safety into his brake system for the models that will reach the showrooms several years from now.

These fluids have an exceptional range of operating temperatures, even below −60°F. Other beneficial characteristics include good lubricity, corrosion and evaporation resistance, and compatibility with other SAE-approved materials. They have sufficient water tolerance to protect against moisture condensation freezing in the brake lines, as well as a minimal swelling effect on rubber.

Dow is currently testing the performance of even more advanced formulations. Some of these fluids may serve in cars that are now little more than a gleam in a designer's eye. Cars with lower silhouettes, for example, may have smaller wheels which generate higher braking temperatures, thus requiring fluids of greater capacity.

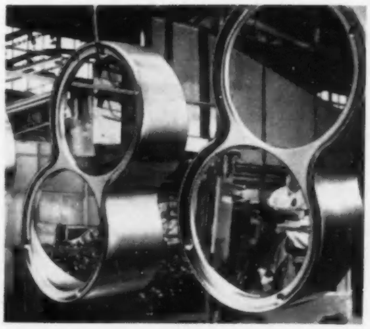
• A look at the coolant crystal ball . . .

In another area of Dow's Automotive Chemicals Laboratories, researchers are also taking the "years ahead" view. Their concern is not how to stop a car, but how to keep it running longer. These men are working on cooling systems and cooling system fluids for all types of engines—large and small, steel and aluminum. They're currently involved in several projects . . . improving corrosion inhibitors, for example . . . perfecting coolants that perform well under extreme conditions.

This continuing research has brought forth several cooling system advances in recent years. Dowgard*, the first year 'round coolant, is "Exhibit A". It replaces antifreeze, water and rust inhibitors in any automotive cooling system.

*TRADEMARK

Simulated radiators test new coolant formulations.



Prior to sub-assembly, parts get a bath in Dow solvents.

• Solvents scrub metal parts

Other Dow chemicals get into the car-making act long before cooling fluid is installed. The extensive group of Dow chlorinated solvents plays a key role in many manufacturing and subassembly operations. These solvents clean metal parts before plating, finishing or assembling, and they do it thoroughly and safely.

There are several of these Dow chlorinated solvents, each designed for specialized use. NEU-TRI® and ALK-TRI®, two grades of Dow trichloroethylene, are widely used in degreasing gears, tappets and other high precision parts. Dow perchloroethylene also serves in the vapor degreaser, particularly on white metal parts. Its high boiling point delivers faster, more thorough cleaning.

Chlorothene®, a safer versatile cold cleaning solvent, helps expedite production and maintenance cleaning of all types—spray, dip, or wipe. Although it is a powerful metal cleaner, Chlorothene is safe to use as a spot cleaner on upholstery.

• Non-skid test tracks

Seems it's increasingly important to automotive engineers that the test track be available for duty 365 days a year. Dow's calcium chloride helps keep the tracks open for business by melting ice in the winter and settling dust in the summer. It does the job quickly, yet its effect is long lasting. It is easy to handle in both the conventional flake form (Dowflake®) and the pellet form (Peladow®).

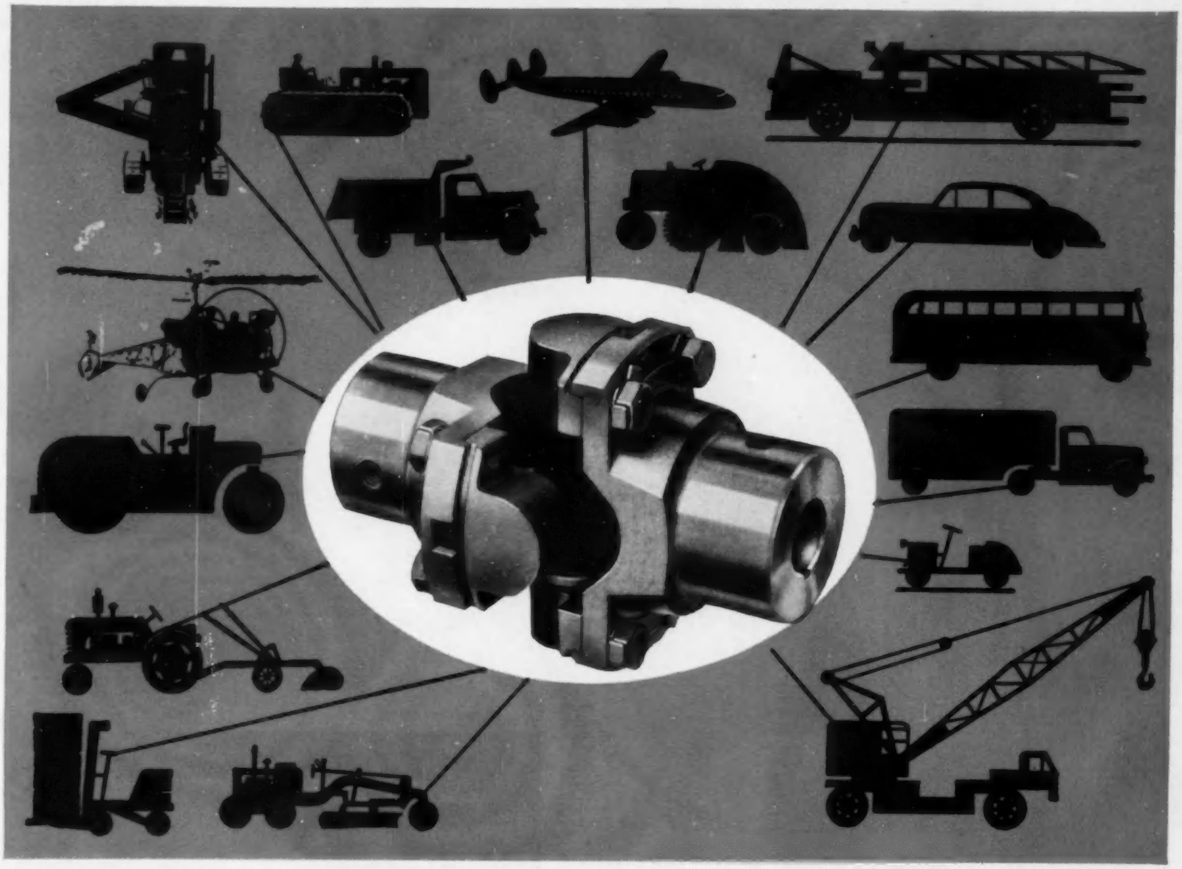
Calcium chloride helps keep test track ice-free, dust-free.

• Your inquiry welcomed

If you'd like to know more about any phase of Dow's activities in automotive chemistry, please write. Your inquiry will receive prompt attention by a member of our technical staff. Contact the Dow sales office near you or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Chemicals Merchandising Dept. 402EN8.

THE DOW CHEMICAL COMPANY
Midland, Michigan

DOW



VERSATILE MECHANICS UNIVERSAL JOINTS Are Used In All Of These Products —And MANY MORE—

VERSATILE MECHANICS Roller Bearing UNIVERSAL JOINTS have been used in almost every type moving vehicle everywhere —on the land—in the air—and in the water. They excel in their use for both main drives and controls—have transmission flanges for any type of brake drum—are easy to service—gives less down time—have long slip—can run at greater angularity—and are of precision high quality. Let our engineers show you how the VERSATILITY of MECHANICS Roller Bearing UNIVERSAL JOINTS will give your products more competitive advantages.

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MECHANICS UNIVERSAL JOINTS

Roller Bearing

• For Cars • Trucks • Tractors • Farm Implements • Road Machinery •
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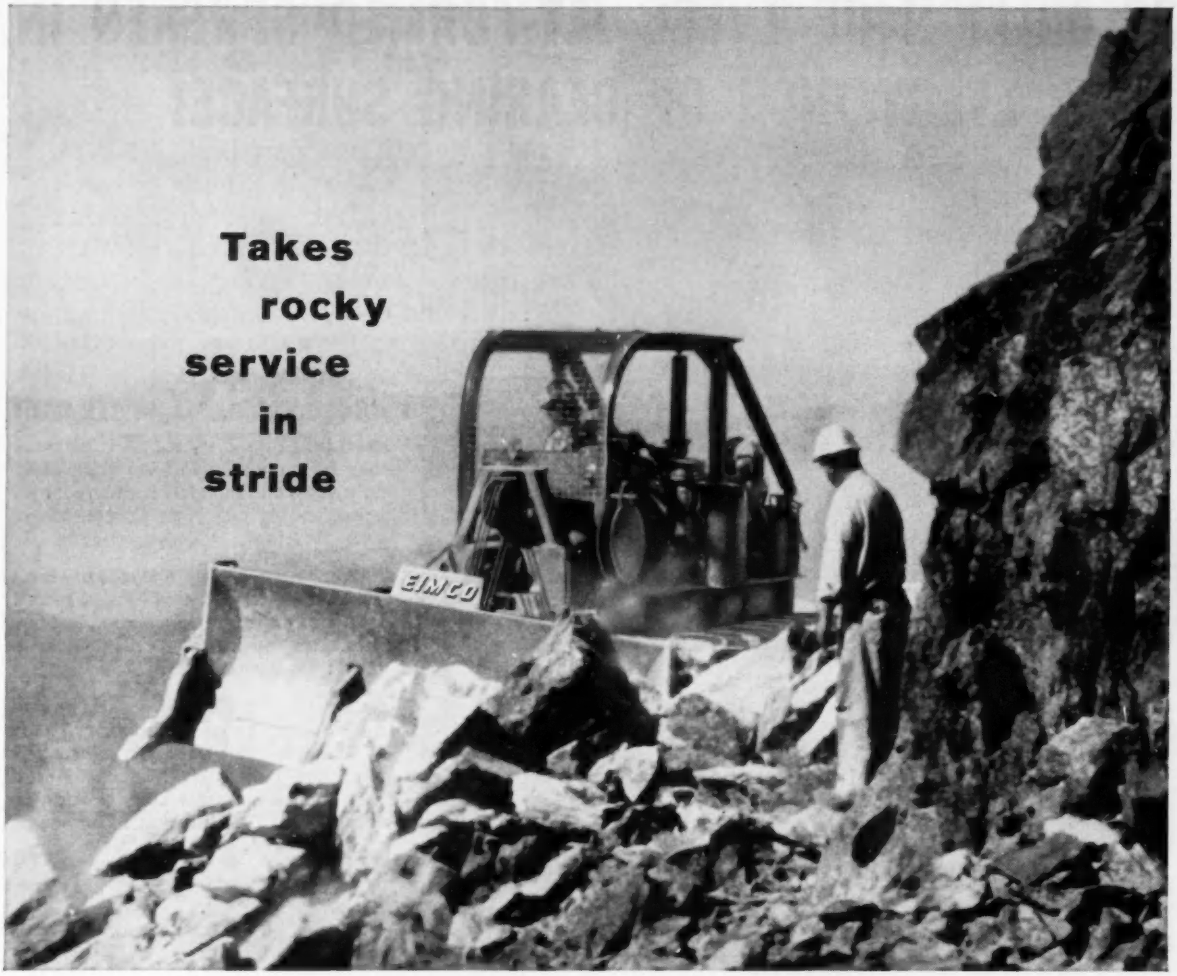
Cross Section of Cold Extruded Piston Pin



Eimco designs with 4 nickel alloy steels for 20,000 hours' service without overhaul

Eimco crawler-tractors like this one have delivered up to 20,000 hours . . . about equal to 30 months of round-the-clock service . . . without any major overhaul. Without even a clutch adjustment.

What accounts for this durability? In transmissions, it's design based on the stamina of four nickel alloy steels. Each was carefully selected by Eimco engineers and metallurgists for its individual combination of strength, adaptability and economy.

4820 and 4620 steels for critical core strength. In all final drives, 4820 is specified for bevel pinions, 4620 for bevel gears. These nickel alloy steels – with outstanding shear strength and fatigue resistance – provide important fabricating benefits, too. They respond consistently to heat treatment . . . have superior resistance to warpage during quenching.

4817 steel for heavy-duty carburizing. Strategically used for heavily-stressed input shafts and drive pinions, this 3½% Nickel steel provides a critical extra measure of resistance to impact and wear.

8620 steel for vital gear hardness. 11 gears in Eimco "Unidrive" transmissions and 15 gears in "Quadra-Torque" drives depend on the carburizing properties of this versatile nickel-containing steel. AISI 8620 possesses the fine machinability plus excellent wear-resistance needed for close-tolerance gearing.

These and other nickel alloy steels – all readily available – can give you the properties you want, in practical combinations for specific requirements in performance, fabrication and economy. If you'd like our help with a special problem in materials selection, simply outline it in an informal letter to Inco.

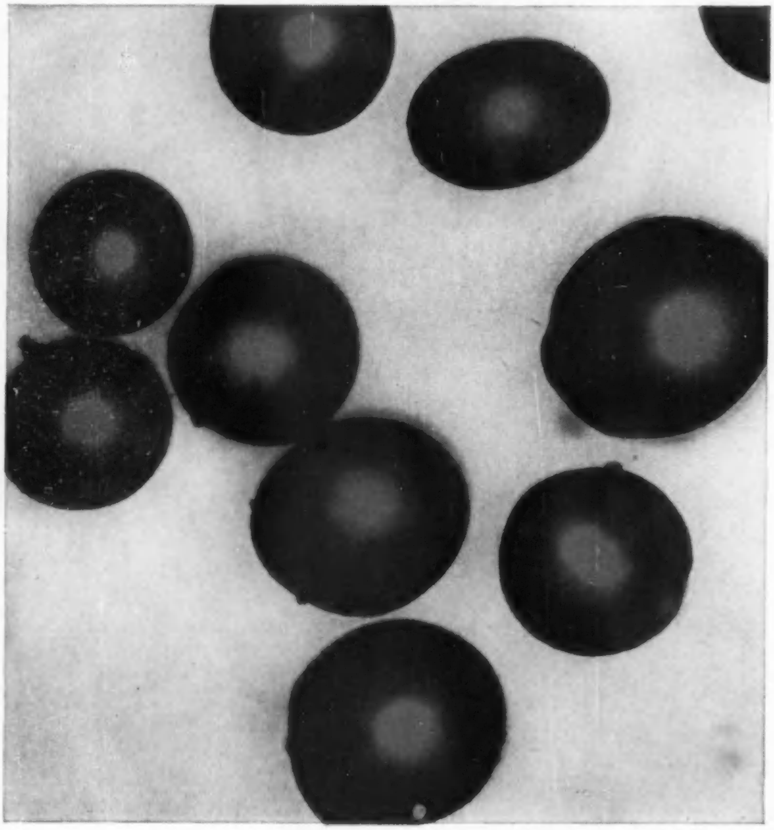
THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N.Y.

INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

★ HEAT TRANSFER ★

30 MILLION OF THESE JET-FORMED SPHERES IN EVERY INCH OF BEARING SURFACE!



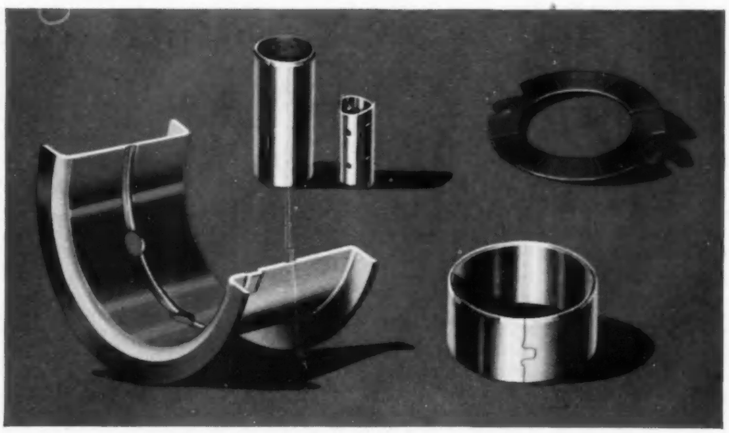
JET PROCESS BLASTS MOLTEN ALLOY INTO UNIFORM PARTICLES . . . so small that thirty million will form a thin layer only one inch square! This sintered layer is the bearing surface of Federal-Mogul sleeve bearings.

Molten copper-lead, alloyed to exact specifications, is poured into a special inert-atmosphere reaction crucible. Here it's blasted by a high-speed fluid jet to form the dense powder shown at left.

Because of the uniform particle size of this powder, the bearing surface of each F-M copper-lead sleeve bearing has precisely the same alloy composition and high adhesion to the steel backing as every other F-M bearing of the same alloy type!

YOU CAN SEE THE CONSISTENT SIZE in the photomicrograph. What you *can't* see is the consistent alloy composition which produces uniform bearing properties and performance in any alloy type.

Federal-Mogul makes engine bearings for every condition of speed and load. You can select from among five different sintered copper-lead alloys, all permanently bonded to precision-formed steel backing. Our Engineering Department is available to you for consultation or recommendations on bearing design and application. For more information, write Federal-Mogul Division, 11035 Shoemaker, Detroit 13, Michigan.



A COMPLETE LINE! Steel backed bearings with a selection of many different alloys for virtually any bearing application—Plain and bimetal bushings in bronze, steel or aluminum. Precision thrust washers in solid bronze, or sintered alloys on steel (one or both faces). Rolled split spacer tubes in steel, aluminum or stainless.

FEDERAL-MOGUL

sleeve bearings
bushings-spacers
thrust washers

DIVISION OF FEDERAL-MOGUL-BOWER BEARINGS, INC.

Take SUSPENSE out of SUSPENSION with LEAF SPRINGS

You can depend on leaf springs!
In addition to prime function, their design characteristics—

- Cushion thrusts of "starts" and "stops"
- Maintain alignment of springs, frame, and axles
- Control load balance
- Minimize sidesway
- Absorb shocks

Simplicity, strength, dependability, and long wear *are inherent in correctly engineered leaf springs.*

DSP *Leaf* **SPRINGS**

DETROIT STEEL PRODUCTS DIVISION
OF *Fenestra* INCORPORATED
6000 Caniff Avenue, Detroit 12, Michigan

Naugatuck KRALASTIC®

New FIAT uses 12 pounds of **KRALASTIC!**

What makes one of the world's leading auto makers turn to KRALASTIC for his new top models? Why are the windshield and window trim, steering-wheel housing and entire dashboard of every new FIAT 2100 and 1800 made of this unique rubber-resin? The answer lies in the material itself.

KRALASTIC's clear-through color eliminates costly finishing operations and at the same time ends fear of unsightly scratching in use. Unlike metals, KRALASTIC never feels cold or clammy to the touch, will never rust, rot or corrode. KRALASTIC weighs less than aluminum. KRALASTIC is easily molded to practically any desired shape or form. KRALASTIC has a self-lubricating quality that helps to eliminate "inevitable" squeaks and rattles. And finally, KRALASTIC provides a combination of toughness and dimensional stability that is unsurpassed.

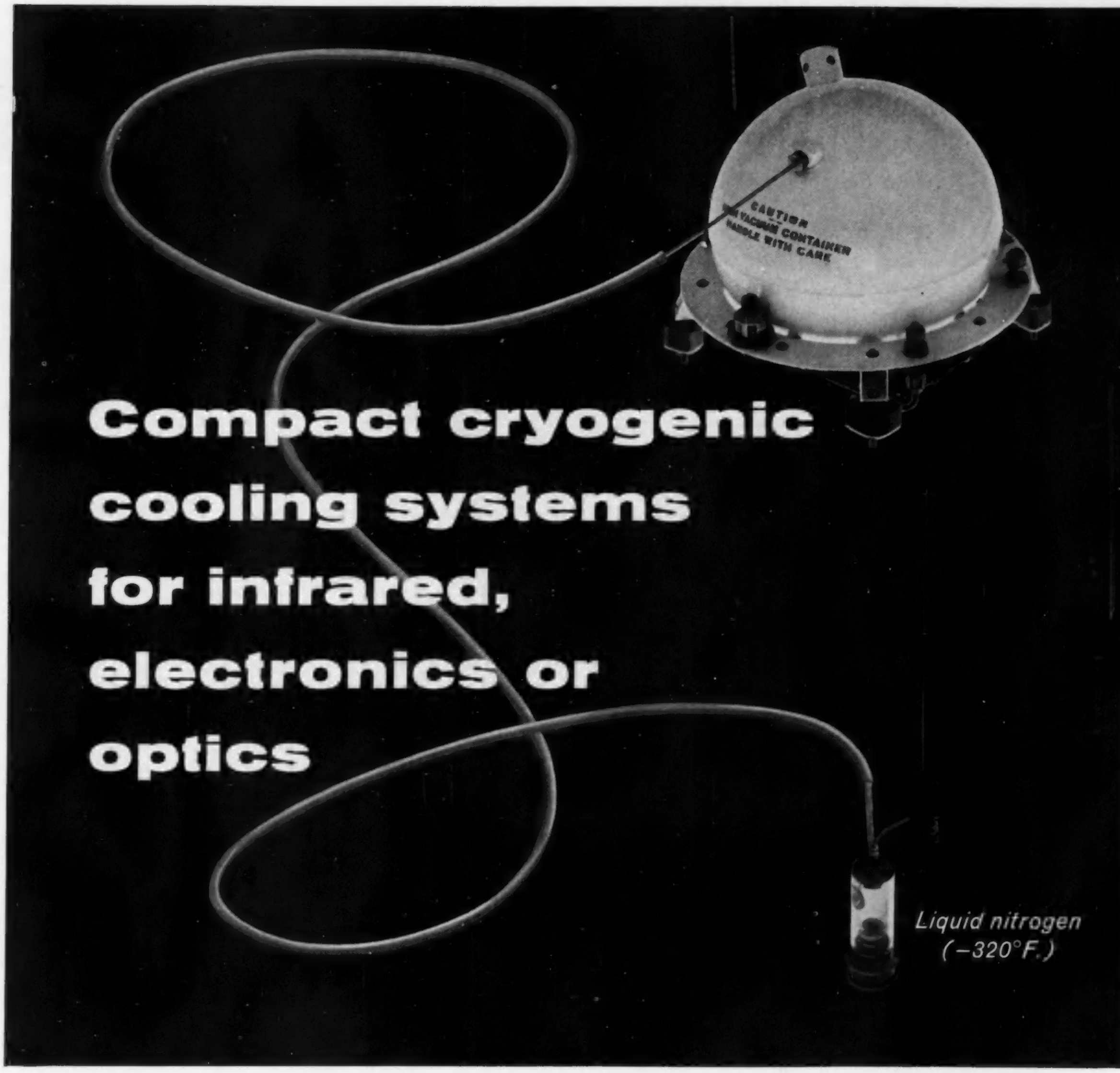
How about your newest, proudest product? Does it enjoy the kind of manufacturing and selling advantages KRALASTIC has already given such varied products as baby combs and water-well pipe? Learn more about this exceptional plastic material now.

United States Rubber

Naugatuck Chemical Division 828K ELM STREET NAUGATUCK, CONNECTICUT

KRALASTIC RUBBER-RESINS • **MARVINOL** VINYLS • **VIBRIN** POLYESTERS

Akron · Boston · Chicago · Gastonia · Los Angeles · Memphis · New York · Phila. · CANADA: Naugatuck Chemicals · Elmira, Ont. · Cable: Rubexport, N.Y.



New AiResearch system delivers nitrogen in liquid form from storage system to cooling area

Now units requiring cryogenic cooling no longer need be designed with allowances made for bulky expanders or adjacent storage tanks.

The new AiResearch system transfers the coolant *in liquid form* to a point of use *25 feet or more away*. The liquefied gas passes through an uninsulated, small, flexible tube which can be bent over and around obstructions. Because the storage system can be placed anywhere, space limitations are overcome and vehicle installation problems are simplified.

The complete system includes the cryogenic liquid container, pressure and flow controls, the liquid transfer tube and cooling adapter. The system can be operated without external power. It can be used with missile, aircraft, space or ground based units and can be converted to a closed-cycle system with the addition of a small gas liquefier.

AiResearch has pioneered many new developments in the cryogenic field. It is presently engaged in work on systems utilizing helium, hydrogen or neon as coolants, and cryogenic systems for zero G operation.

• *Please direct inquiries to Los Angeles Division.*

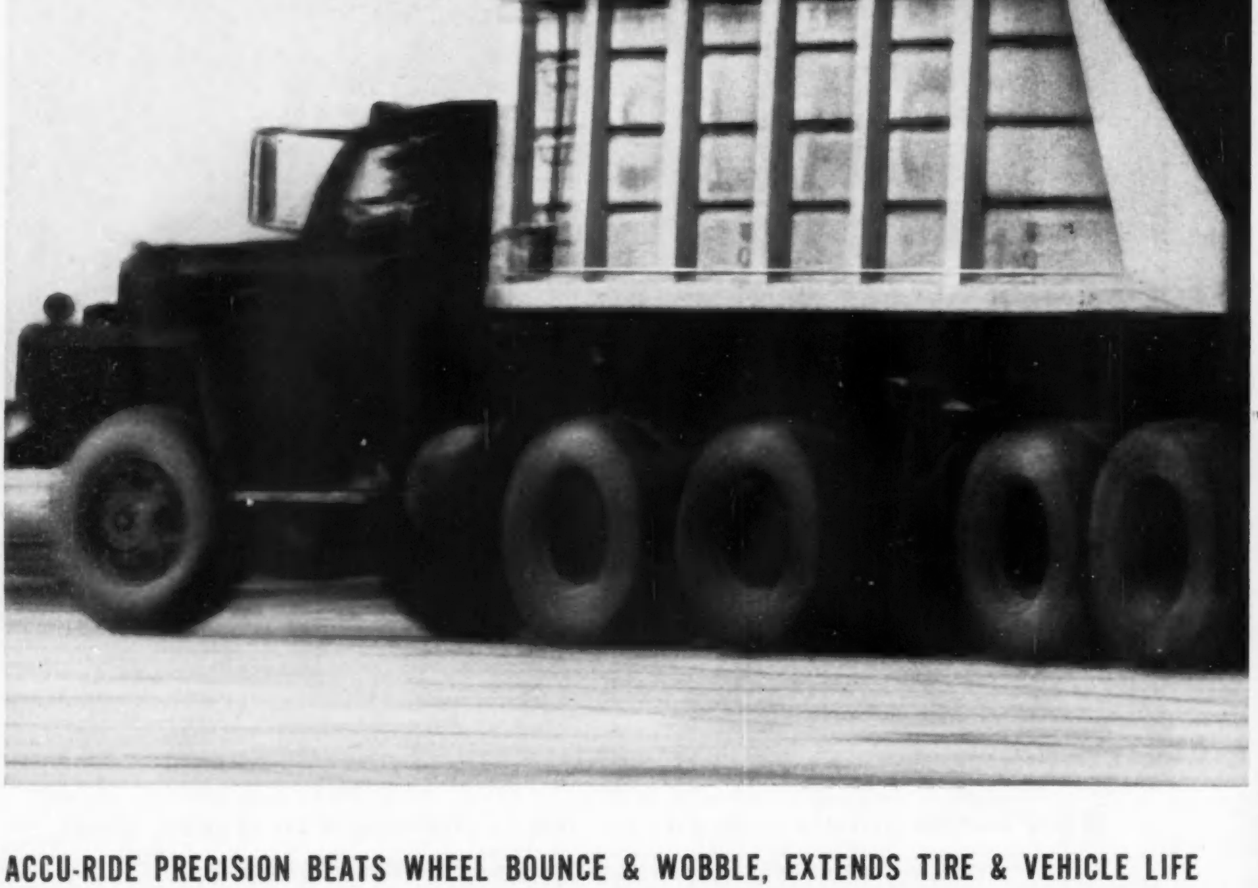
THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems and Components for: AIRCRAFT, MISSILE, SPACECRAFT, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

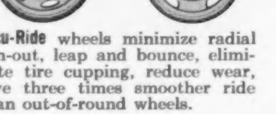
ACCU-RIDE® WHEELS SMOOTH THE



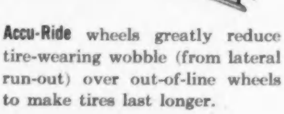
ACCU-RIDE PRECISION BEATS WHEEL BOUNCE & WOBBLE, EXTENDS TIRE & VEHICLE LIFE

NO OTHER MASS-PRODUCED WHEEL SMOOTHS THE ROAD LIKE FIRESTONE ACCU-RIDE. JUST TRY A SET ON THE FRONT—AND PROVE IT FOR YOURSELF! THEY REDUCE "WHEEL FIGHT" SO MUCH YOU'LL THINK YOU HAVE POWER STEERING! Accu-Ride wheels are years ahead and made possible only by Firestone's advanced metal-working technology. The Accu-Ride disc wheel is the truest-rolling steel wheel ever made and the coolest-running wheel to withstand today's high-speed, heavy-load operating conditions. Accu-Ride precision engineering permits a maximum of vehicle and tire life. That's because Accu-Ride wheels are spin-formed for maximum control of dimensions, improvement of strength characteristics and perfect balance. Its continuous Thruweld provides a joint twice as strong as any other fastening of a rim to a disc. Exclusive Firestone Perma-Plate finish beats corrosion. And Accu-Ride wheels are available *at no extra cost* for every truck, bus and truck-trailer on the road. They are performance-proved by eight years and 150 million miles of tests. For further information on Firestone Accu-Ride wheels—or Firestone Precision Rims—write, wire or call the Firestone Technical Service Man at Firestone Steel Products Co., Department 45(9) Akron 1, Ohio.

HERE'S HOW ACCU-RIDE WHEELS PAY OFF

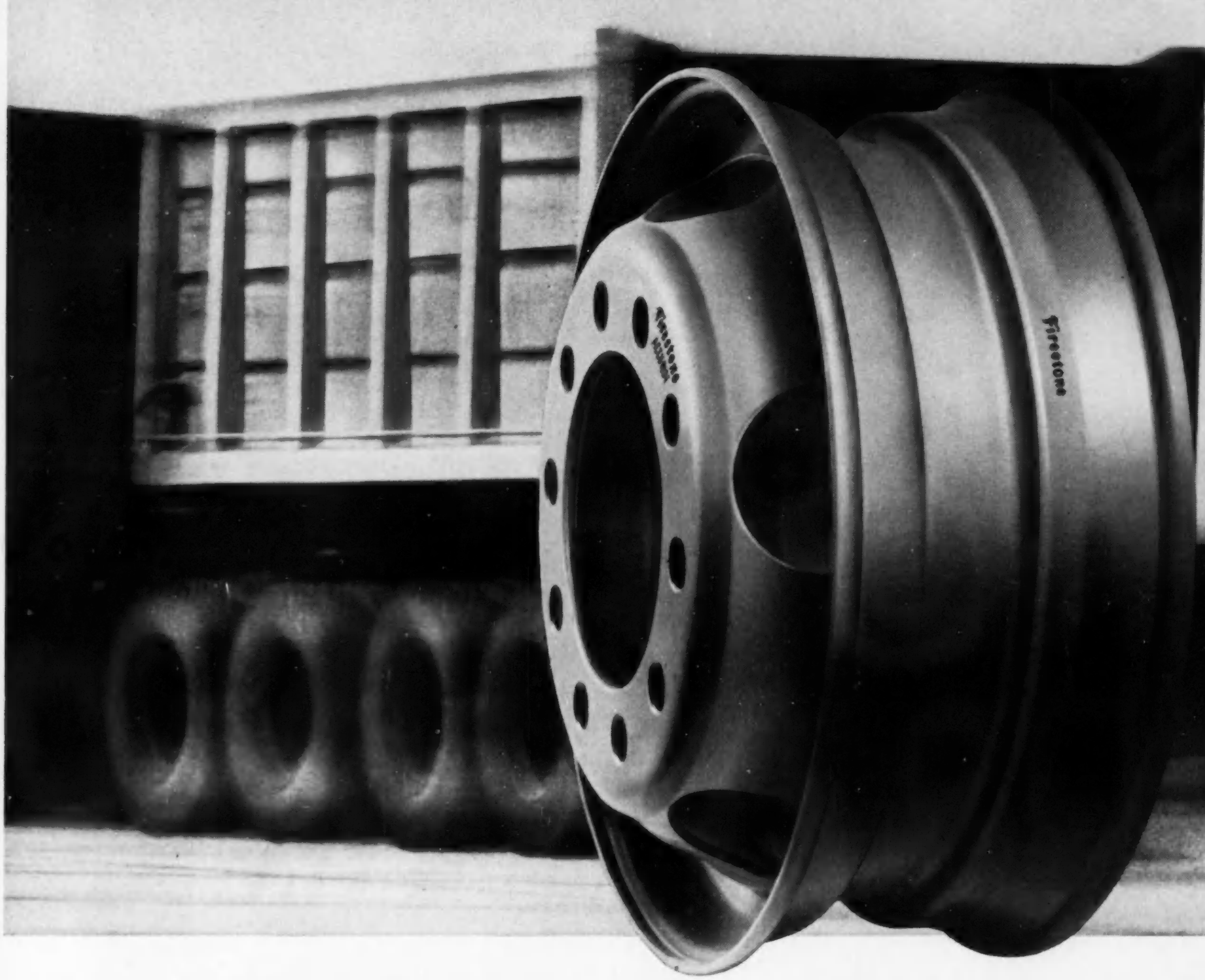


Accu-Ride wheels minimize radial run-out, leap and bounce, eliminate tire cupping, reduce wear, give three times smoother ride than out-of-round wheels.



Accu-Ride wheels greatly reduce tire-wearing wobble (from lateral run-out) over out-of-line wheels to make tires last longer.

ROAD FOR TRUCK AND LOAD!



FIRESTONE TIRE-TAILORED PRECISION-CORRECT RIMS MEAN EXTRA TIRE MILES, TOO!

Firestone's precision-correct, compression-fit truck and bus rims give complete support to tires, put full tread width on pavement for maximum traction, longer tread life, lower cost-per-mile performance. They are tailored to make tires fit better and last longer and are available on Accu-Ride wheels for both tube-type and tubeless tires. All Firestone rims are protected with exclusive corrosion-proof Firestone Perma-Plate finish.

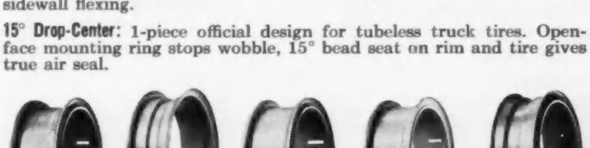
5° Commander: World's most popular 3-piece rim. Stress-tested, fleet-proved. Full bead support, wide base design, continuous side ring.

RH5°: 2-piece disc wheel rim. Continuous side ring, full bead support and wide base eliminate rocking, reduce flexing for longer tire life.

FL5° Challenger: Full-offset, work-weight, tube-type rim. Eliminates bead chafing, rocking. Will do heavy work usually expected from heavier rims.

N5° Challenger: Lightest weight tube-type rim made. Weighs up to 10 lbs. less than comparable rim. 5° bead support reduces tire rocking, sidewall flexing.

15° Drop-Center: 1-piece official design for tubeless truck tires. Open-face mounting ring stops wobble, 15° bead seat on rim and tire gives true air seal.



5° Commander **RH5°** **FL5° Challenger** **N5° Challenger** **15° Drop-Center**

Firestone

STEEL PRODUCTS COMPANY
AKRON 1, OHIO
INTEGRITY, QUALITY, ACCURACY, DEPENDABILITY

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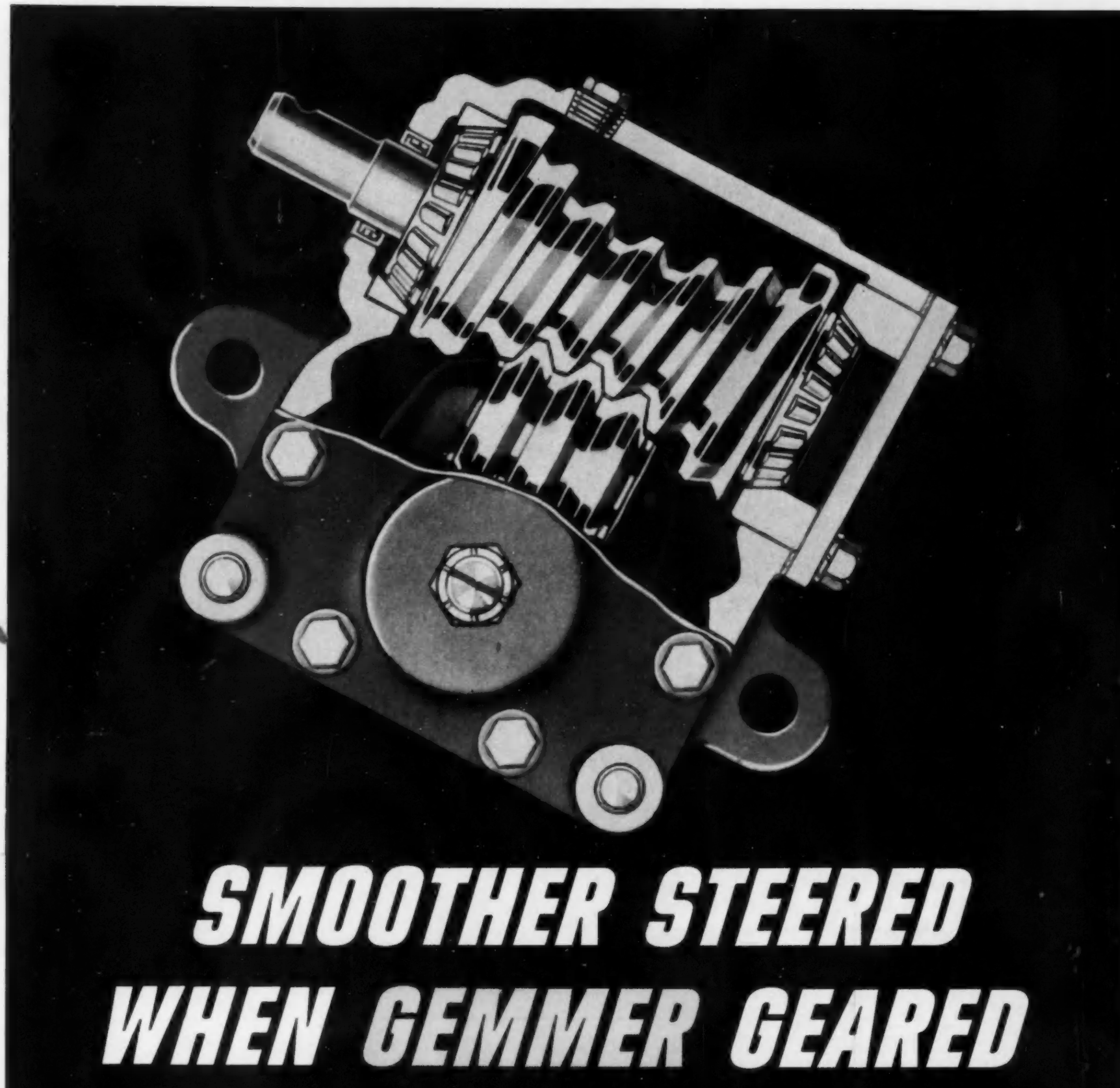

Gemmer steering is engineered for strength and ease of operation . . . built for lifetime service and minimum maintenance. Customer pleasing features of the 7D gear are:

Compactness . . . High numerical ratio of 28:1 . . . An efficient, rugged gear . . . Simplicity of installation and adjustment . . .

Available in either malleable or aluminum housings

For *your* steering needs, Gemmer offers you experience as old as the industry.

Gemmer steering
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GEMMER MANUFACTURING COMPANY, Detroit, Michigan • Division of Ross Gear & Tool Company, Inc.

TIMKEN®

Fine Alloy **STEEL**

Ready-made savings for your hollow parts

Why bore out bar stock to make your hollow parts? Start with Timken® seamless steel tubing; the hole's already there. You save drilling costs, steel, machining time and you're sure of uniform quality finished parts, too. That's because we make Timken steel tubing by forging a solid round over a mandrel, thoroughly working the metal inside and out. This gives the tubing its fine forged quality and uniform spiral grain flow.

When you buy Timken steel you always get: 1) *Quality* that's uniform from heat to heat, tube to tube, order to order; 2) *Service* from the experts in specialty steels; 3) Over 40 years of *experience* in solving tough steel problems. Let our engineers help you save by recommending the most economical tube size for your hollow parts job . . . one guaranteed to clean up to your finish dimensions. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits*

TIMKEN ALLOY STEEL AND SEAMLESS STEEL TUBING ARE AVAILABLE FROM STEEL SERVICE CENTERS IN 44 CITIES IN THE UNITED STATES